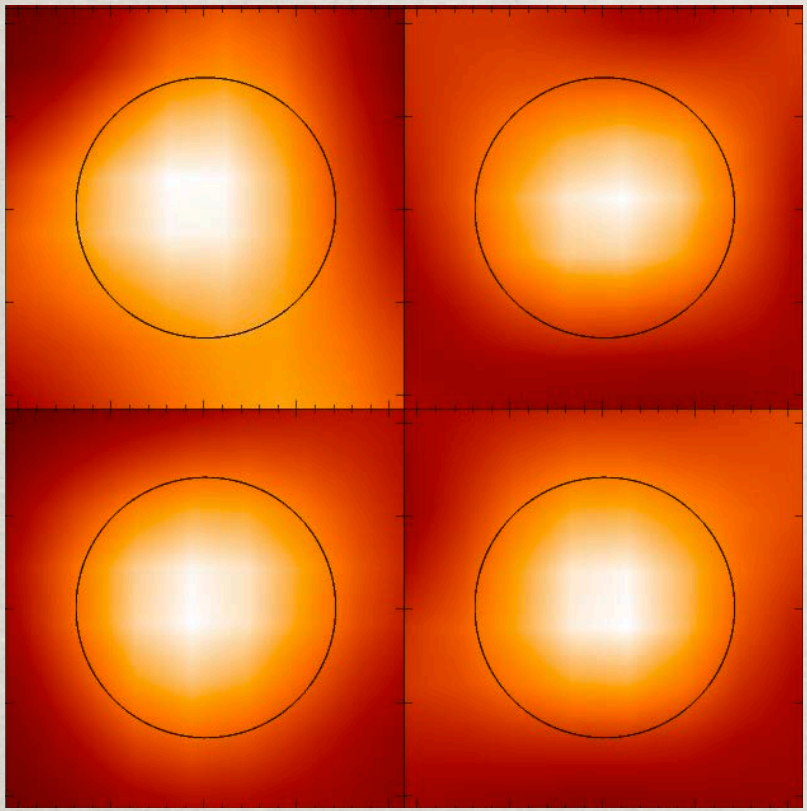
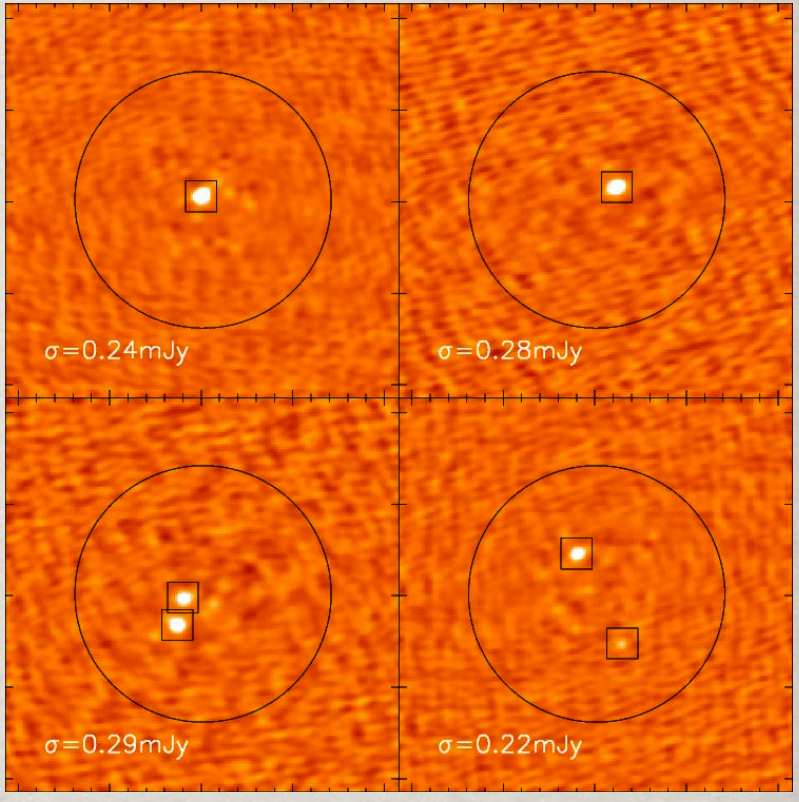
The ALMA LESS survey

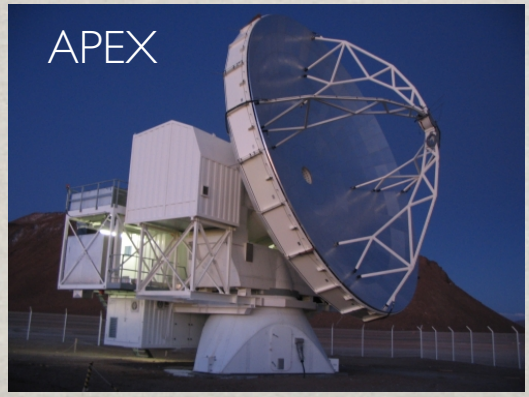
James Simpson (Durham)

pre-ALMA



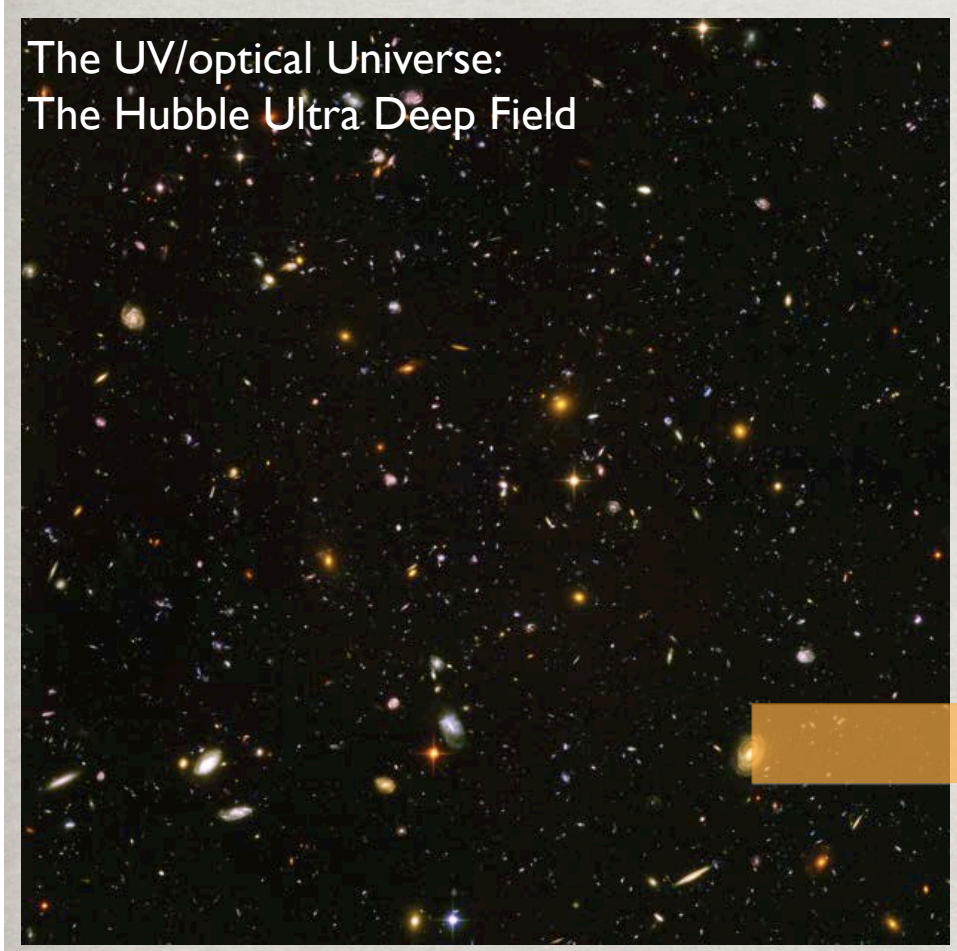
with ALMA

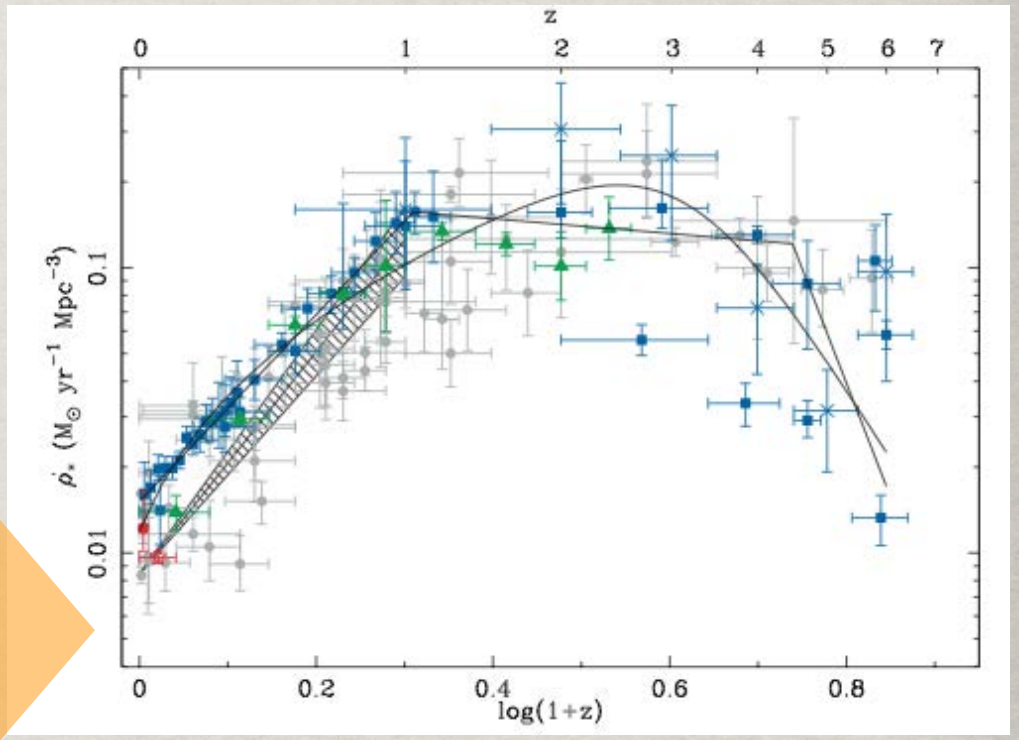




Mark Swinbank, Jackie Hodge, Alex Karim, Ian Smail, Fabian Walter,
++ the ALMA-LESS consortium

Epoch of Galaxy Formation





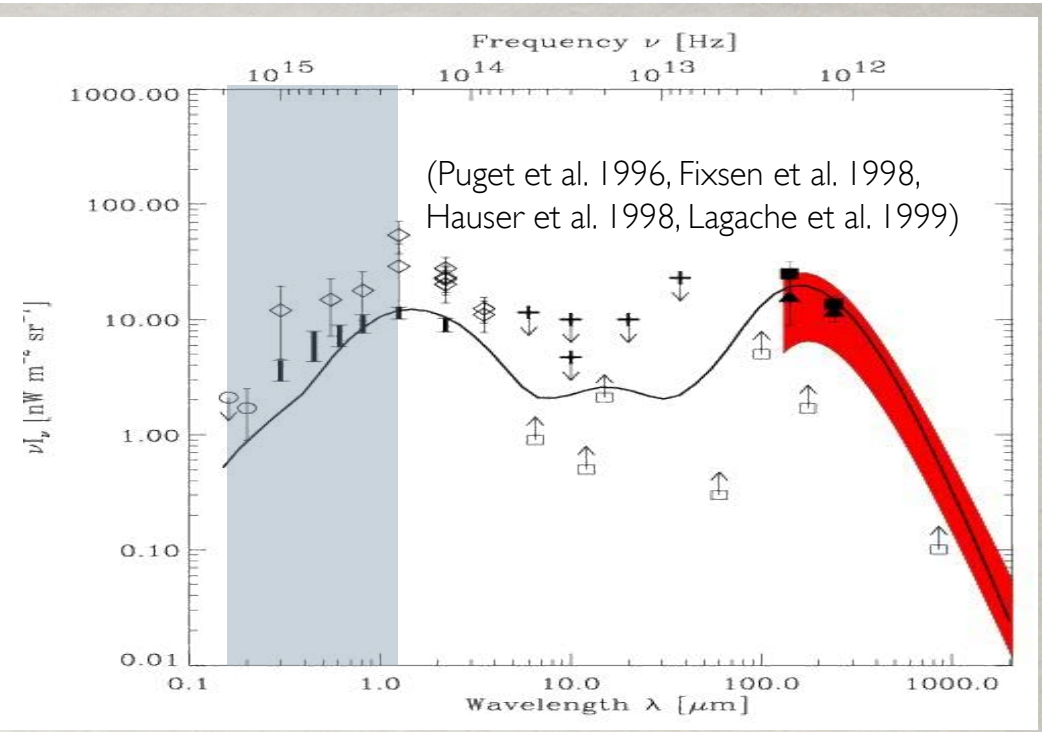
Hopkins & Beacom 2006

- Background in UV and optical is mainly dominated by stars (rather than AGN)

- Luminosity density can be used to track the evolution of the star-formation with redshift to identify the epoch of galaxy formation

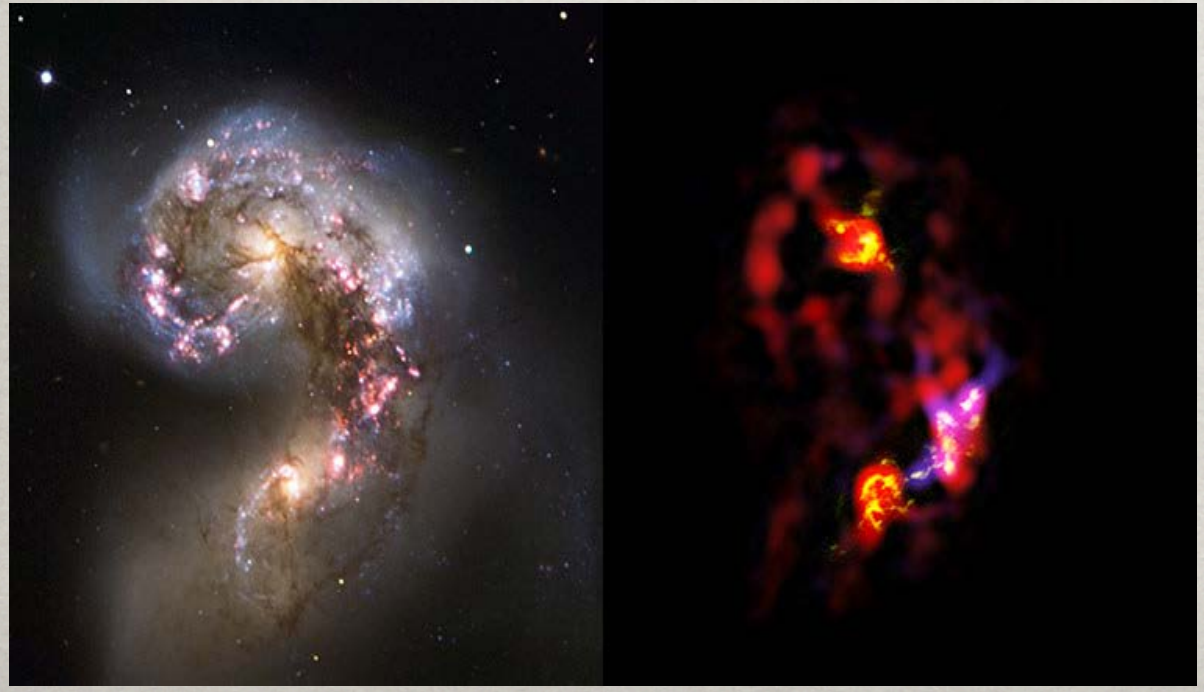
•COBE showed that ~50% of the light produced by extra-galactic objects has been reprocessed by dust and re-emitted in the far infrared and sub-mm.

•Far Infrared background = opt/UV --> half of the energy production (from SF or AGN) over history of the Universe arises in highly obscured regions



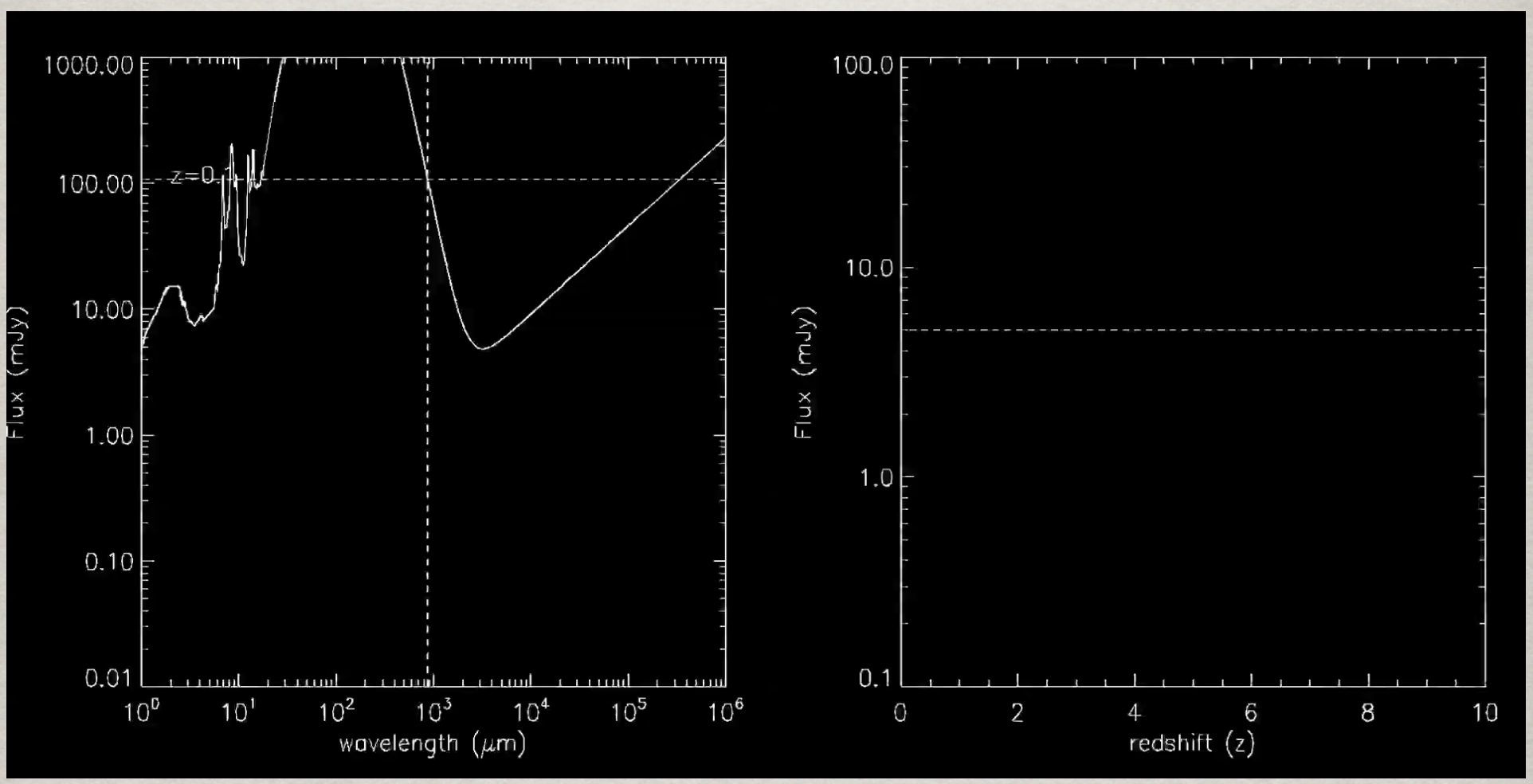
HST - optical

Herschel 250-500μm

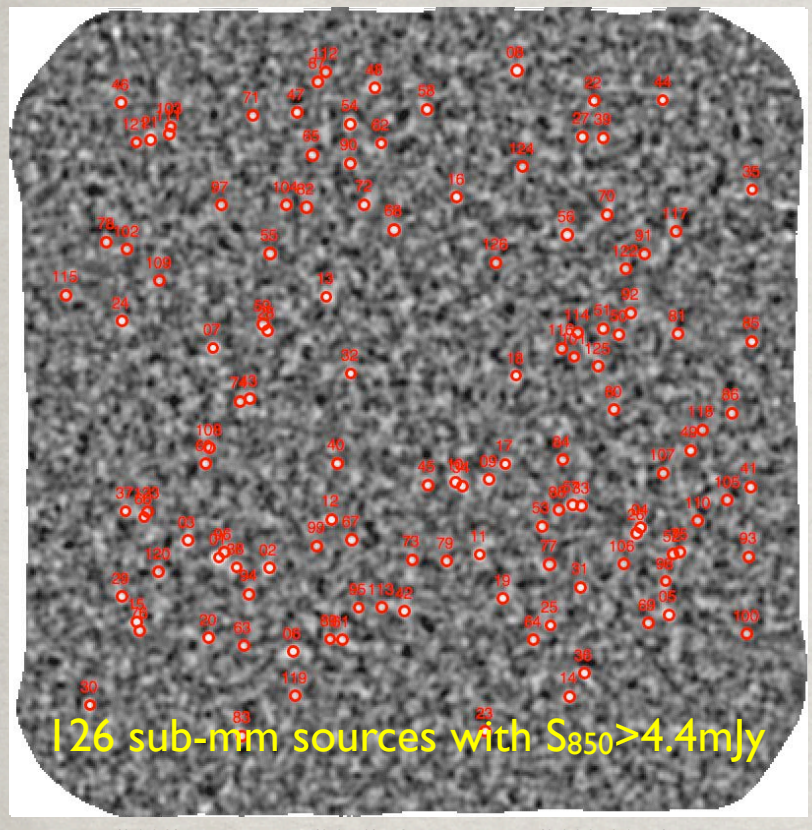


- Most luminous FIR gals at z~0 are UltraLuminous InfraRed Galaxies (ULIRGs)
- $L_{FIR}>10^{12}L_o$, inferred SFRs 100's M_o/yr
- >95% Luminosity comes out in FIR (~10-1000um)
- Host <1% of star formation at z=0 - maybe more important at high-z?

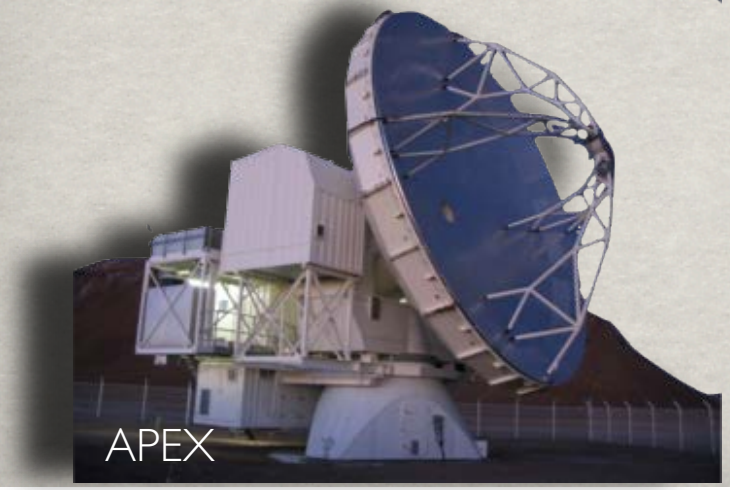
The negative k-correction in the sub-mm wave-bands



LABOCA Extended Chandra Deep Field South Survey (LESS)

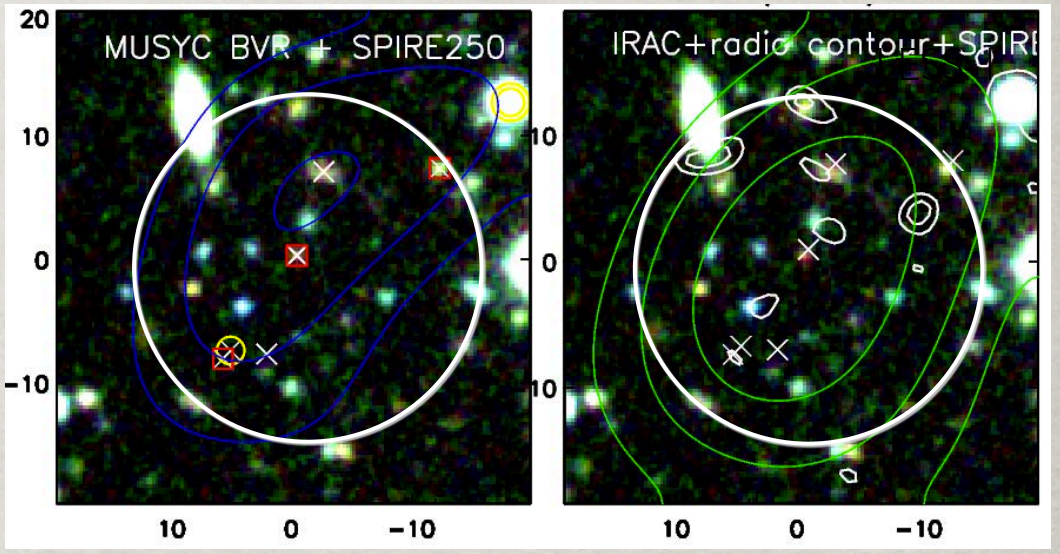


Weiss et al. (2009); Biggs et al. (2010); Coppin et al. (2009, 2011); Dunlop et al. (2010); Greve et al. (2011); Hickox et al. (2011); Wardlow et al. (2011); Chapin et al. (2011); de Breuck et al. (2011); Nagao et al. (2012)



The ECDFS is the prime extra-galactic survey field, with wealth of multi-wavelength data from Chandra X-ray; UV/optical+mid-IR; HSO SPIRE; APEX LABOCA and VLA radio.

LESS is a contiguous & uniform 870μm survey, reaching σ_{870}=1.2mJy over ~30x30'



λ/D~18" (so lots of possible counterparts for each sub-mm source)

Adding Herschel imaging does not improve situation for IDs since resolution is ~15", 25" and 35" at 250, 350 & 500μm

CREDIT: ALMA (ESO/NAOJ/NRAO)/W. Garnier (ALMA)

The ALMA LABOCA Extended Chandra Deep Field South Survey (A-LESS)

Survey all 126 sub-mm sources in ECDFS at 870um (345GHz) to depth of 0.3mJy in compact configuration.

2 mins / source (c.f. 300hours with APEX to 1.2mJy)

Crucially, at a resolution of 1.4"

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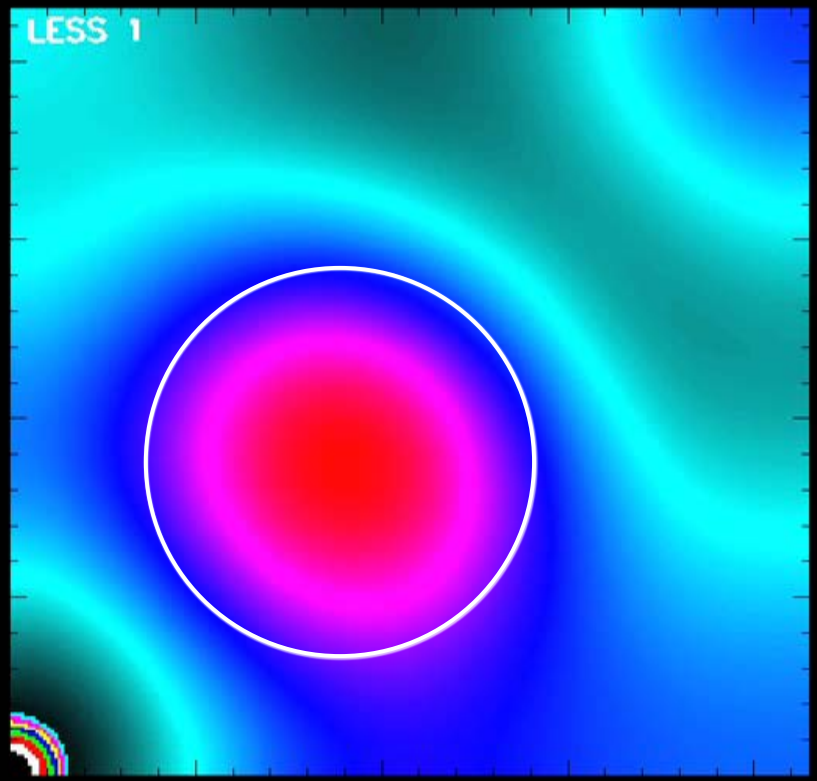
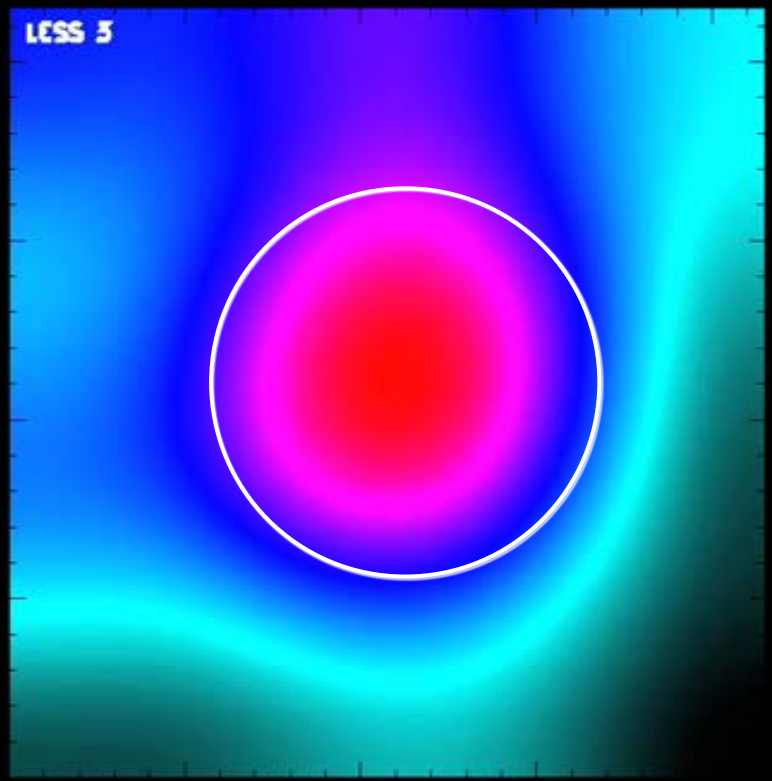
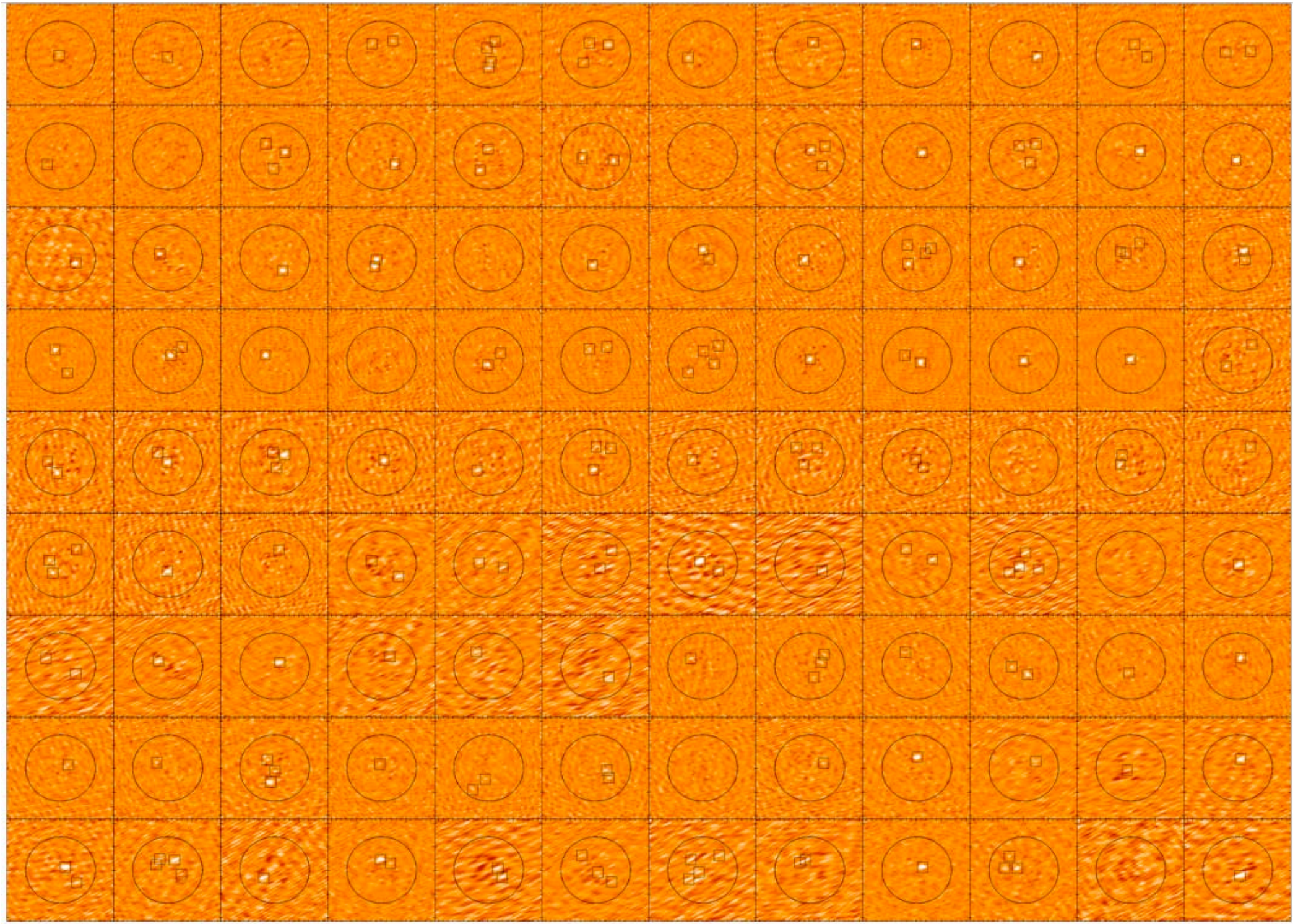
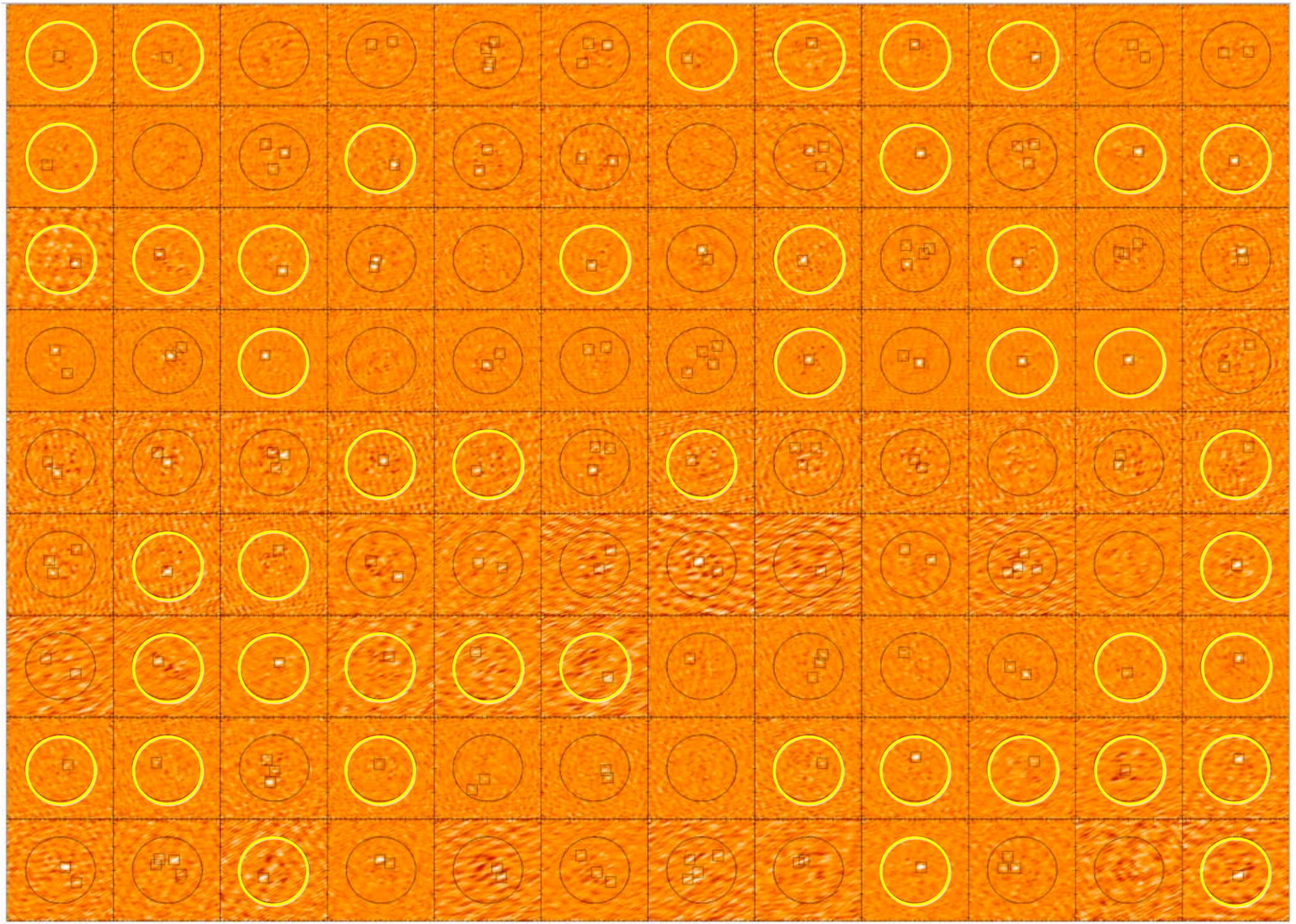
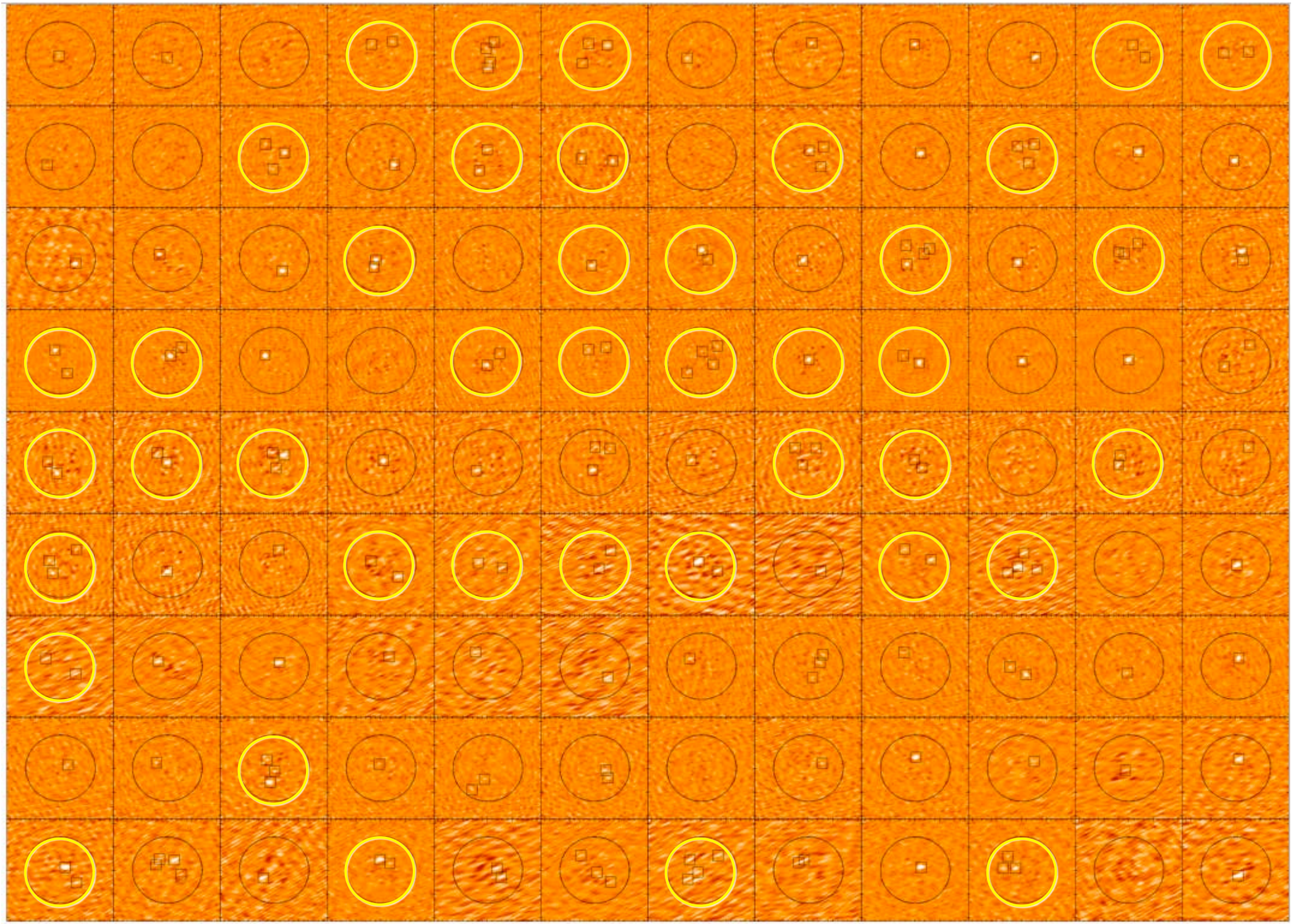
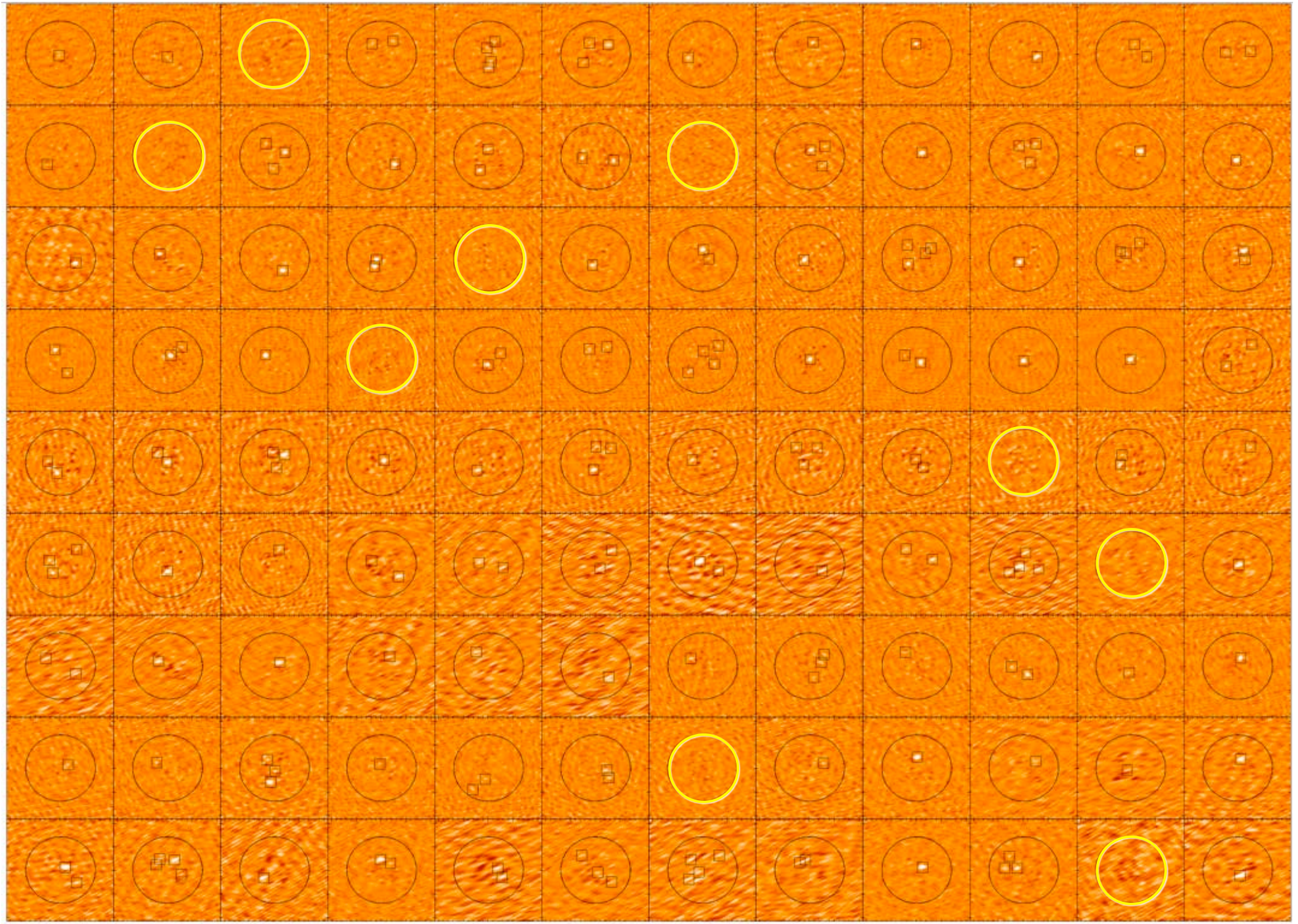


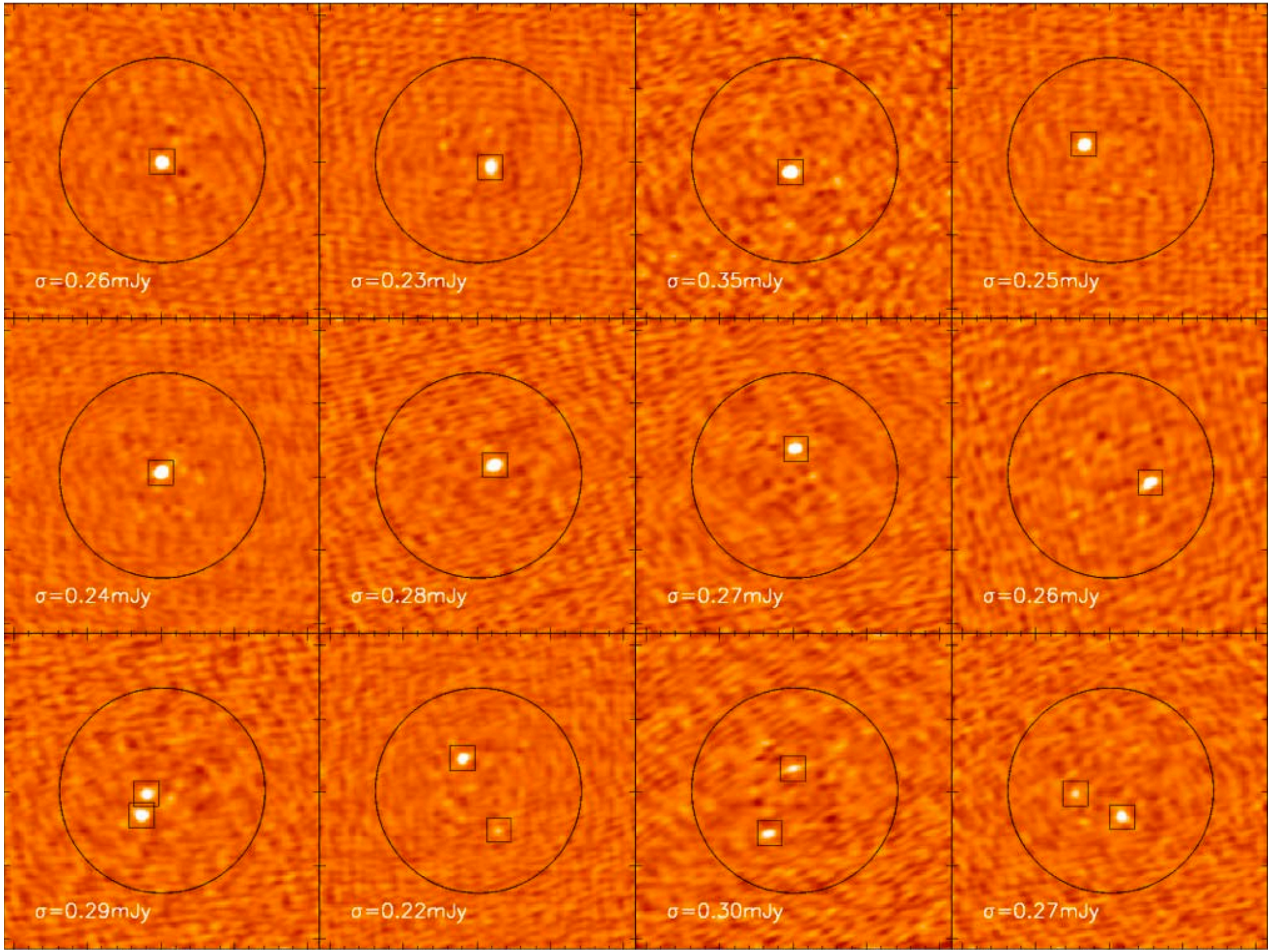


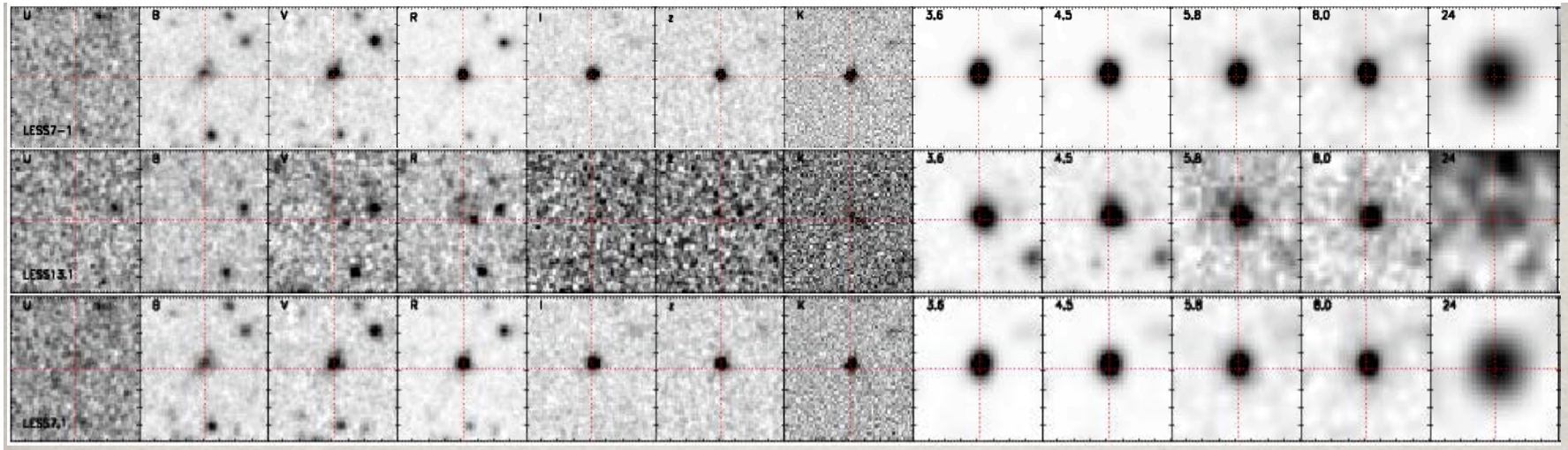




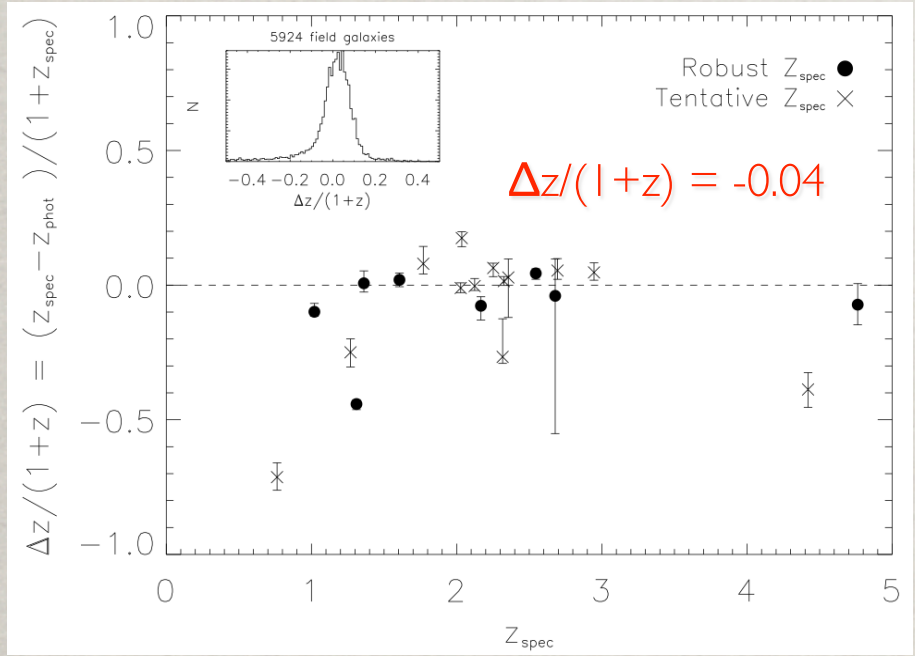


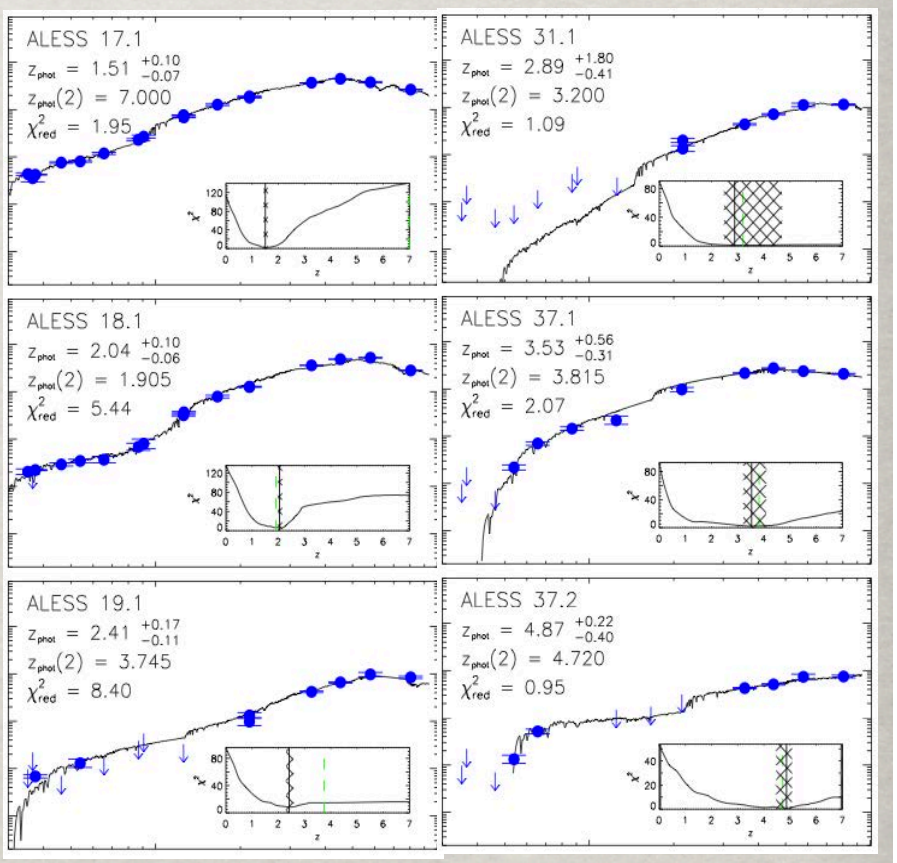



σ=0.26mJy
σ=0.23mJy
σ=0.35mJy
σ=0.25mJy
σ=0.24mJy
σ=0.28mJy
σ=0.27mJy
σ=0.26mJy
σ=0.29mJy
σ=0.22mJy
σ=0.30mJy
σ=0.27mJy



ECDFS deep archival imaging: UBVRIzJHK +IRAC



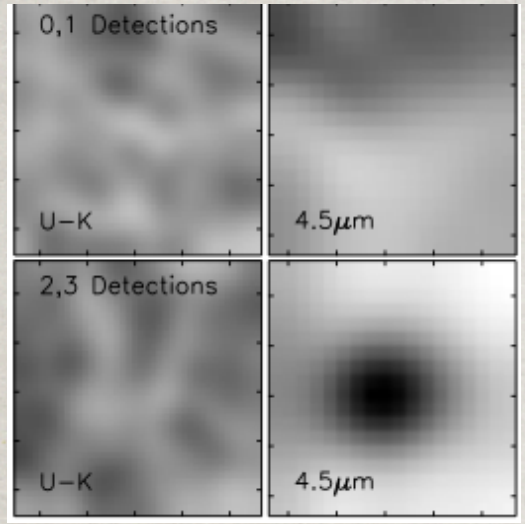


- 96 ALMA SMGs
- Calibrate against 5900 field galaxies in ECDFS
- ~25 SMGs with spec-z's
- Derive photo-z for 77 SMGs with > 3 band photometry

Simpson et al. 2013 ApJ Submitted

BUT:

- 19 SMGs (20% of sample) have 0-1 detections (9) or 2-3 detections (10) in UV/optical/NIR/mid-IR bands
- Real or just S/N effects in 870um catalog?



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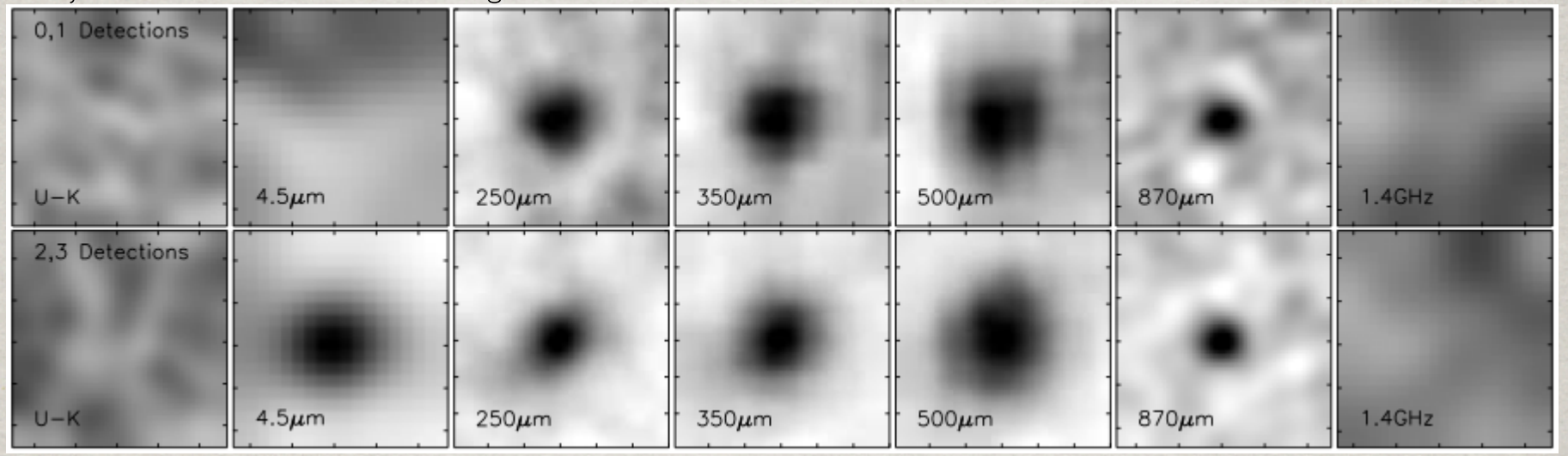
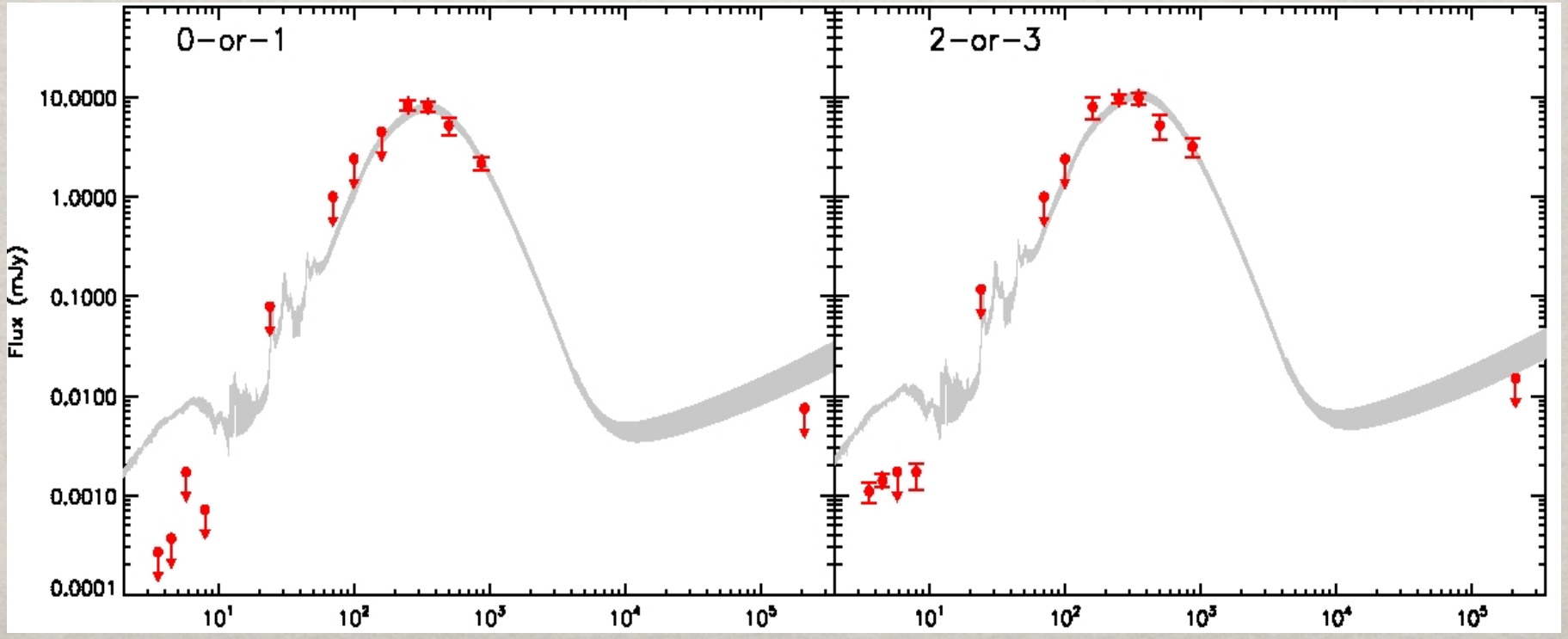
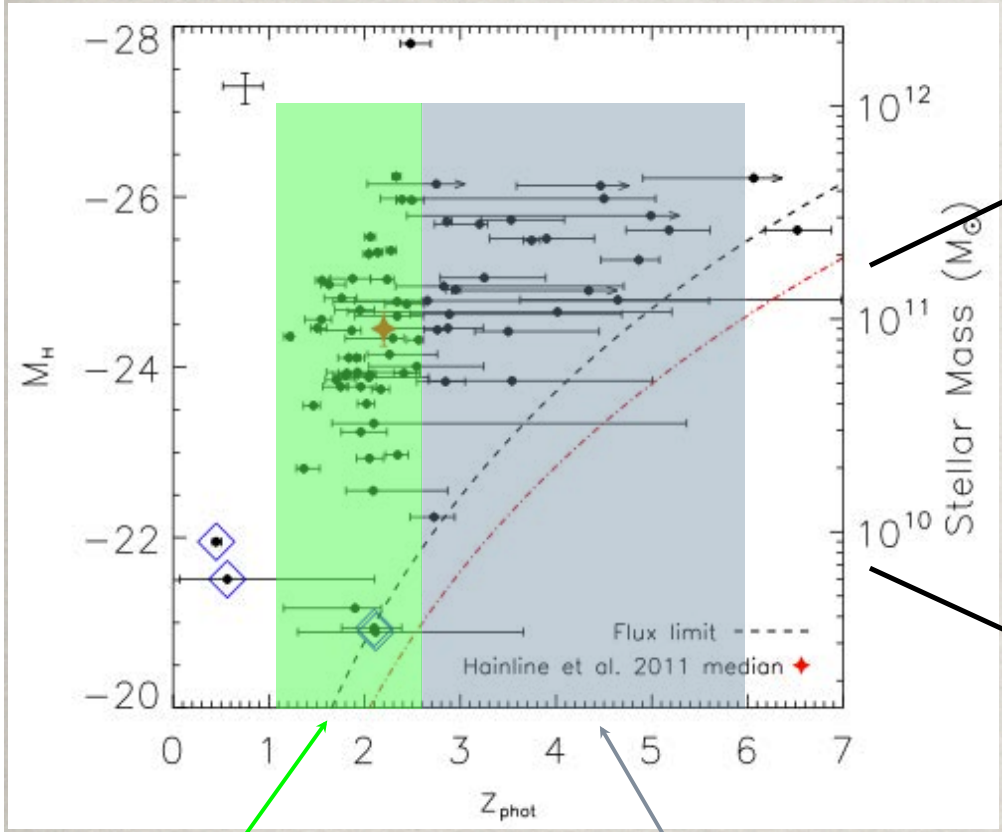




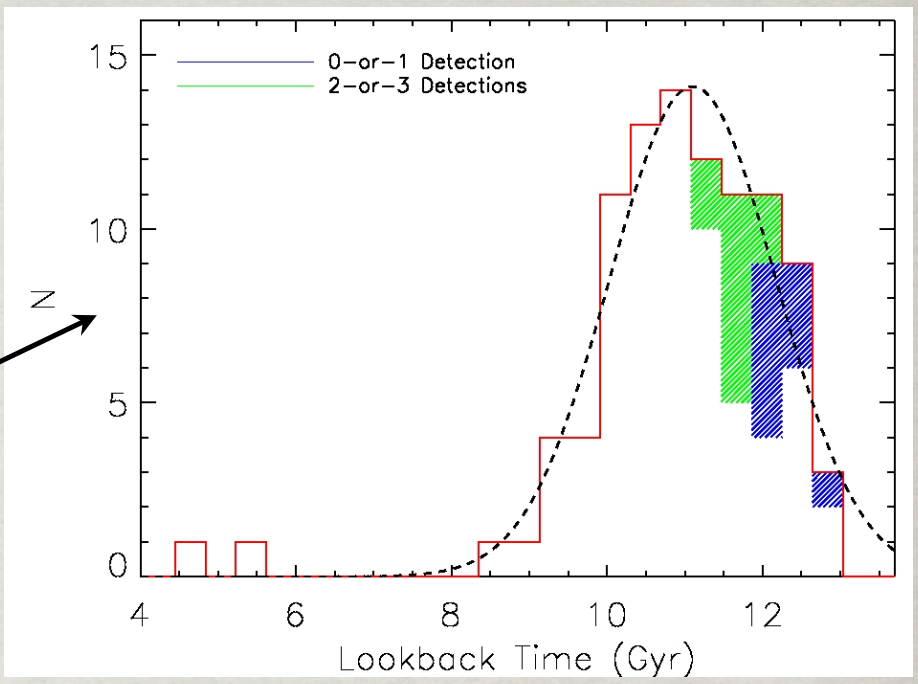
Magnitude distribution and stellar mass



Assume to z=2.5 we have "correct" M_H distribution

MC to derive underlying distribution at z>2.5

N(t) for ALESS SMGs



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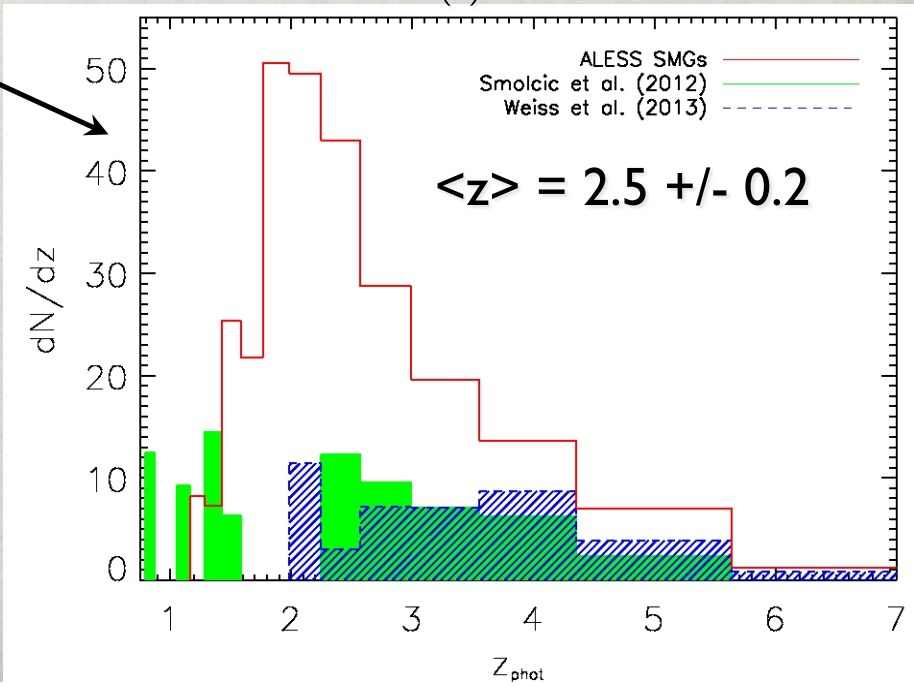
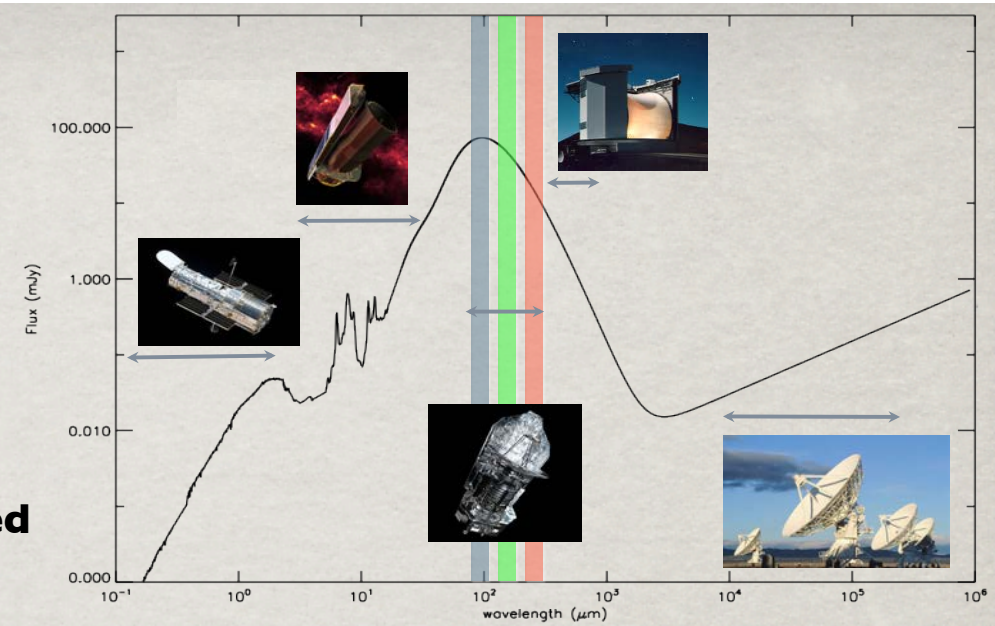
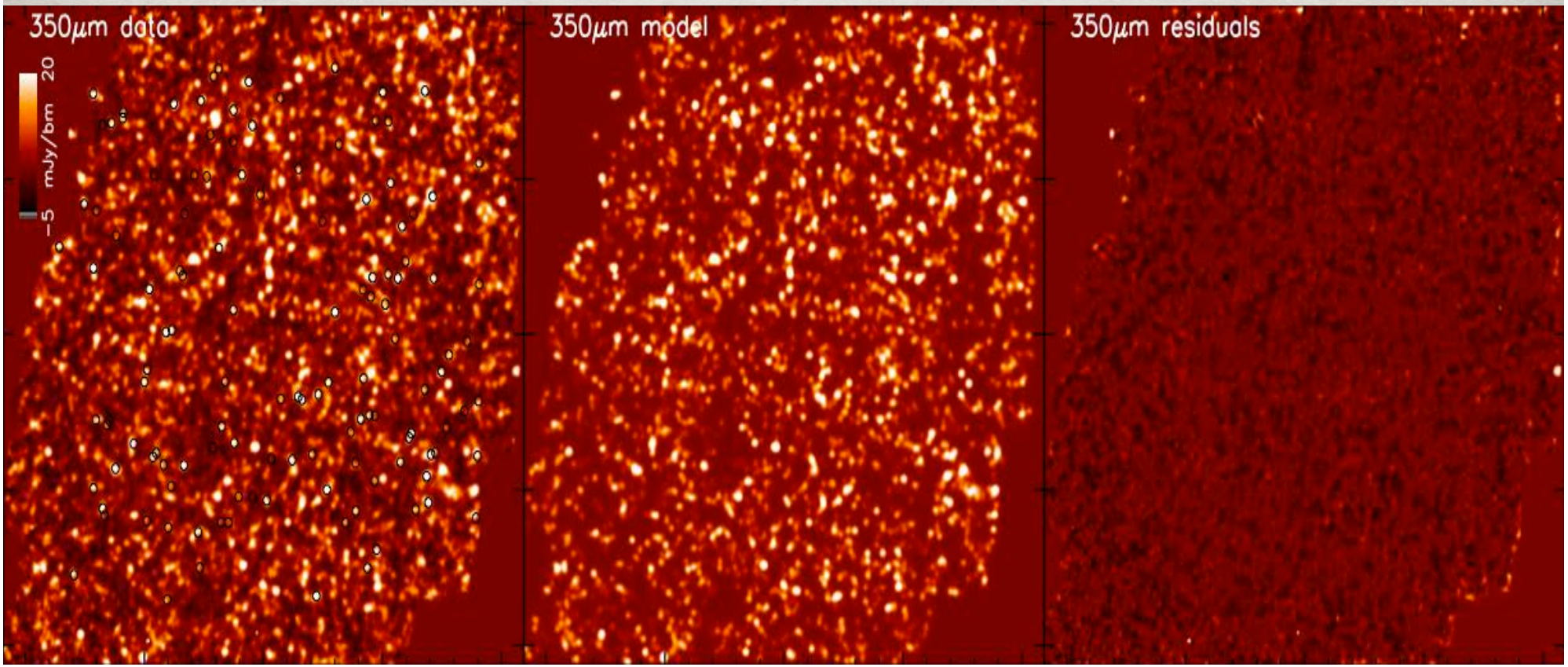


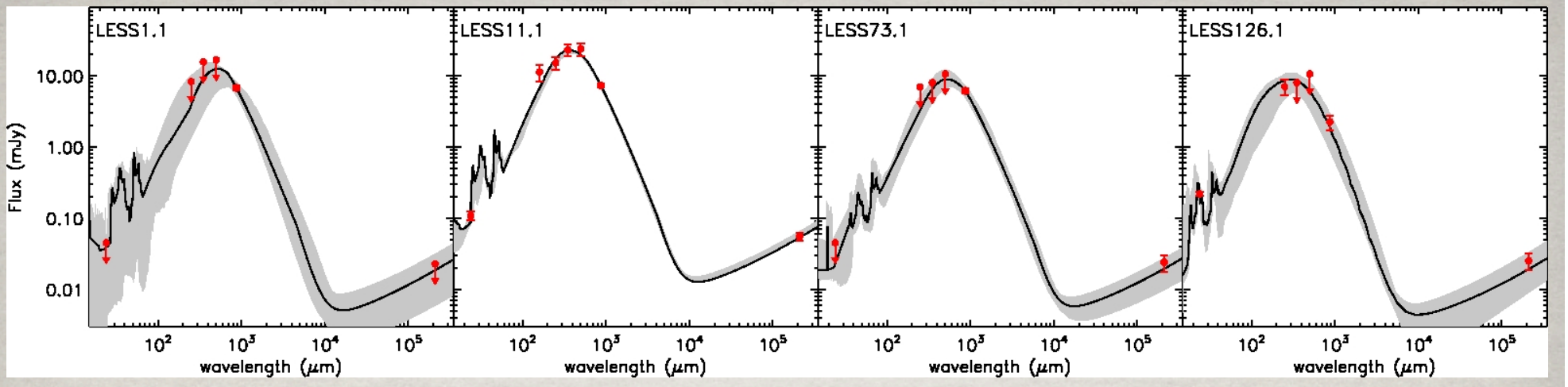
Herschel SPIRE 250, 350, 500μm imaging allows us to improve measurement of far-IR SEDs of ALMA SMGs

But need to deblend SPIRE maps (use 24 and radio imaging as prior catalogs)

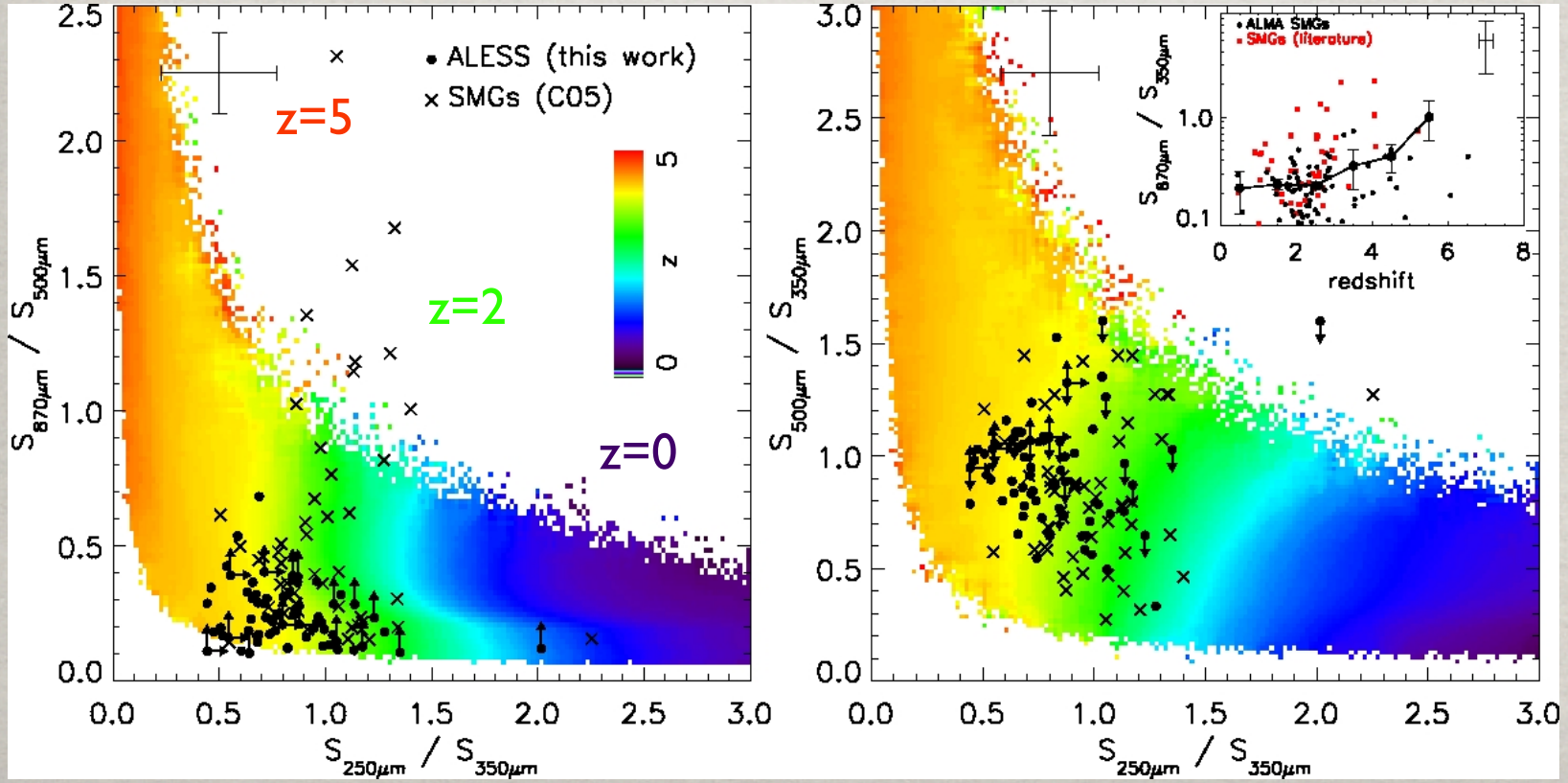
Swinbank et al. 2013 MNRAS submitted

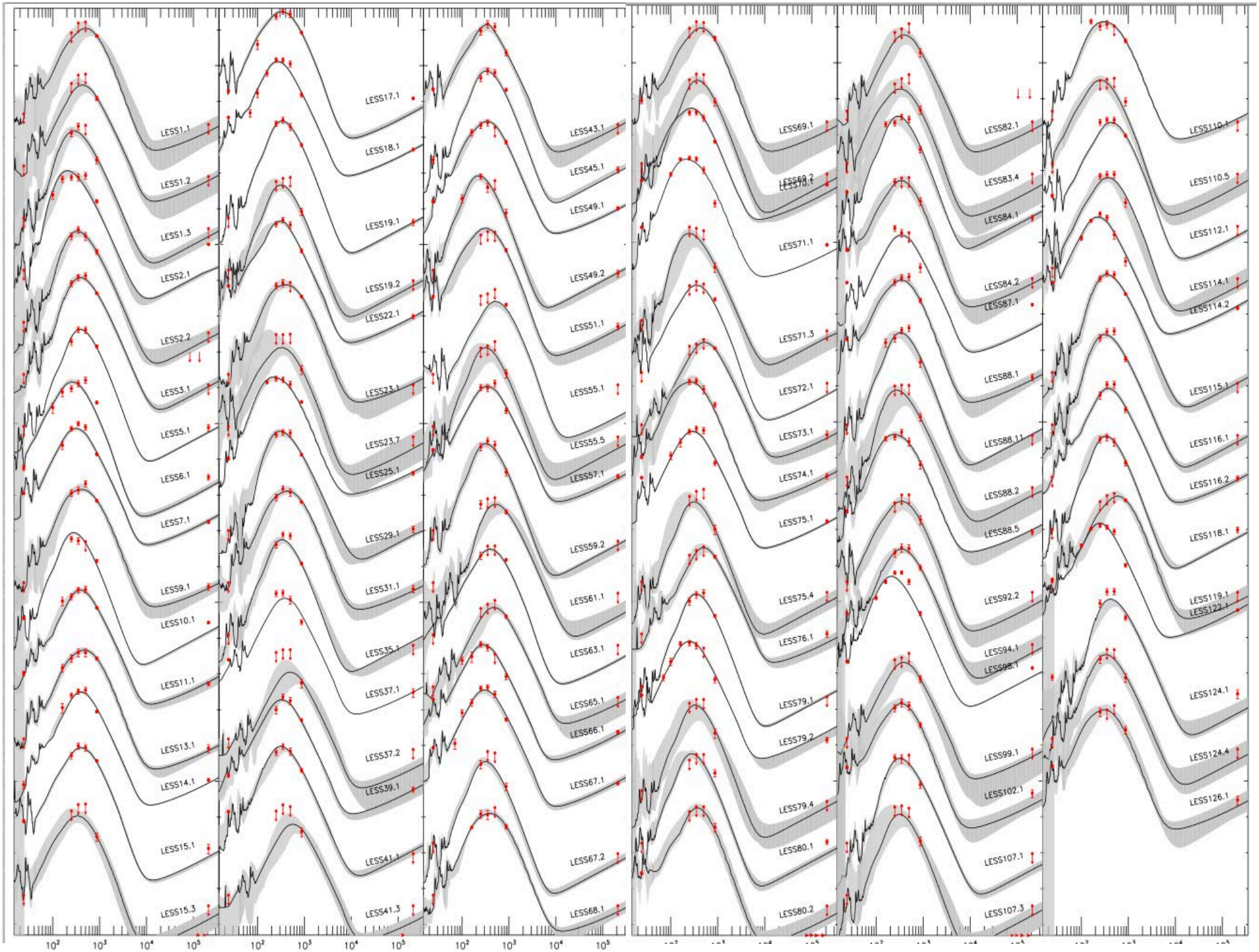






25+/-3 % peak at 250μm (<z> ~ 2.3) 38+/-3 % peak at 350μm (<z> ~ 2.5) 37+/-8 % peak at 500μm (<z> ~ 3.5)




LESS1.1
LESS1.2
LESS1.3
LESS2.1
LESS2.2
LESS3.1
LESS5.1
LESS6.1
LESS7.1
LESS9.1
LESS10.1
LESS11.1
LESS13.1
LESS14.1
LESS15.1
LESS15.3
LESS17.1
LESS18.1
LESS19.1
LESS19.2
LESS22.1
LESS23.1
LESS23.7
LESS25.1
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LESS37.2
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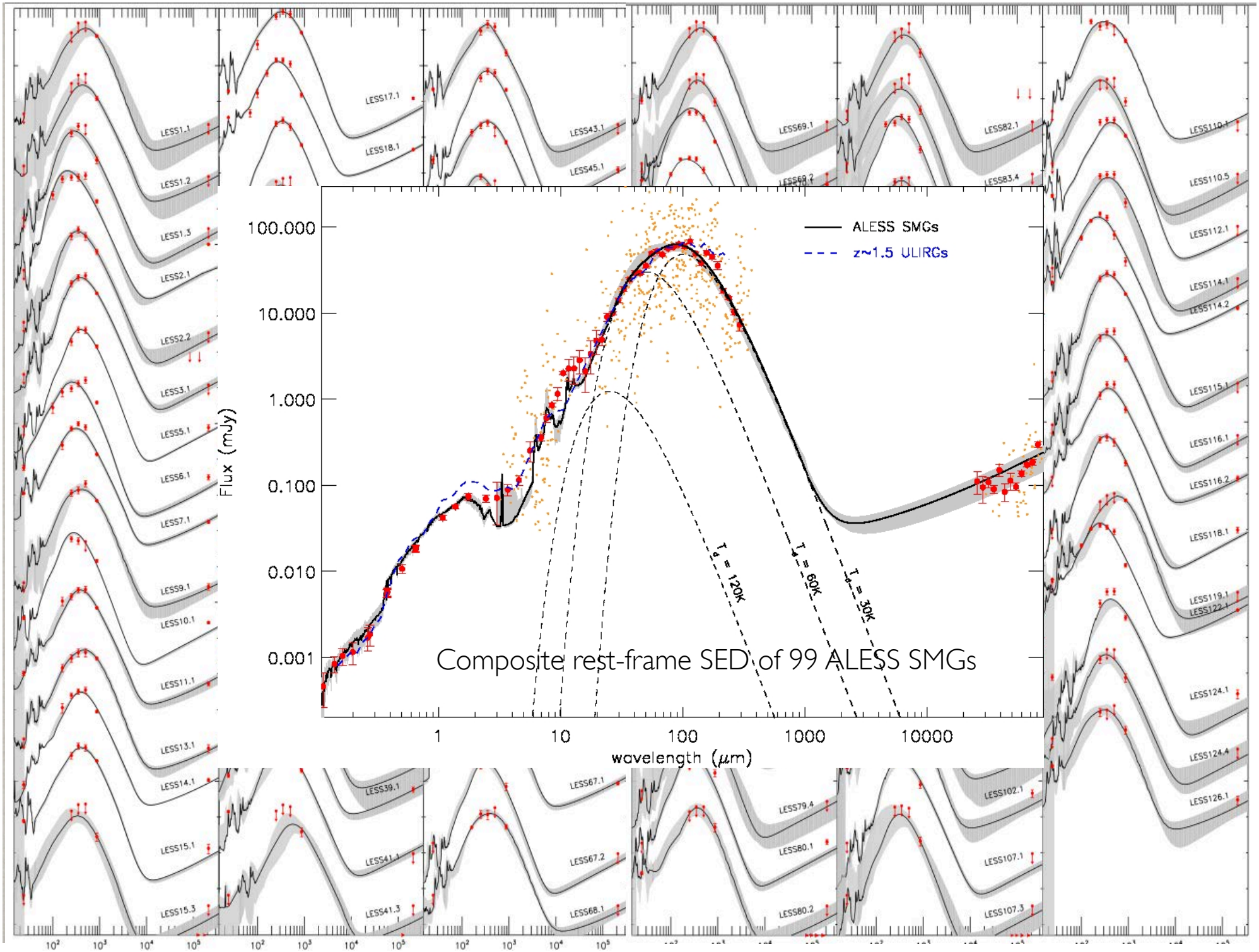
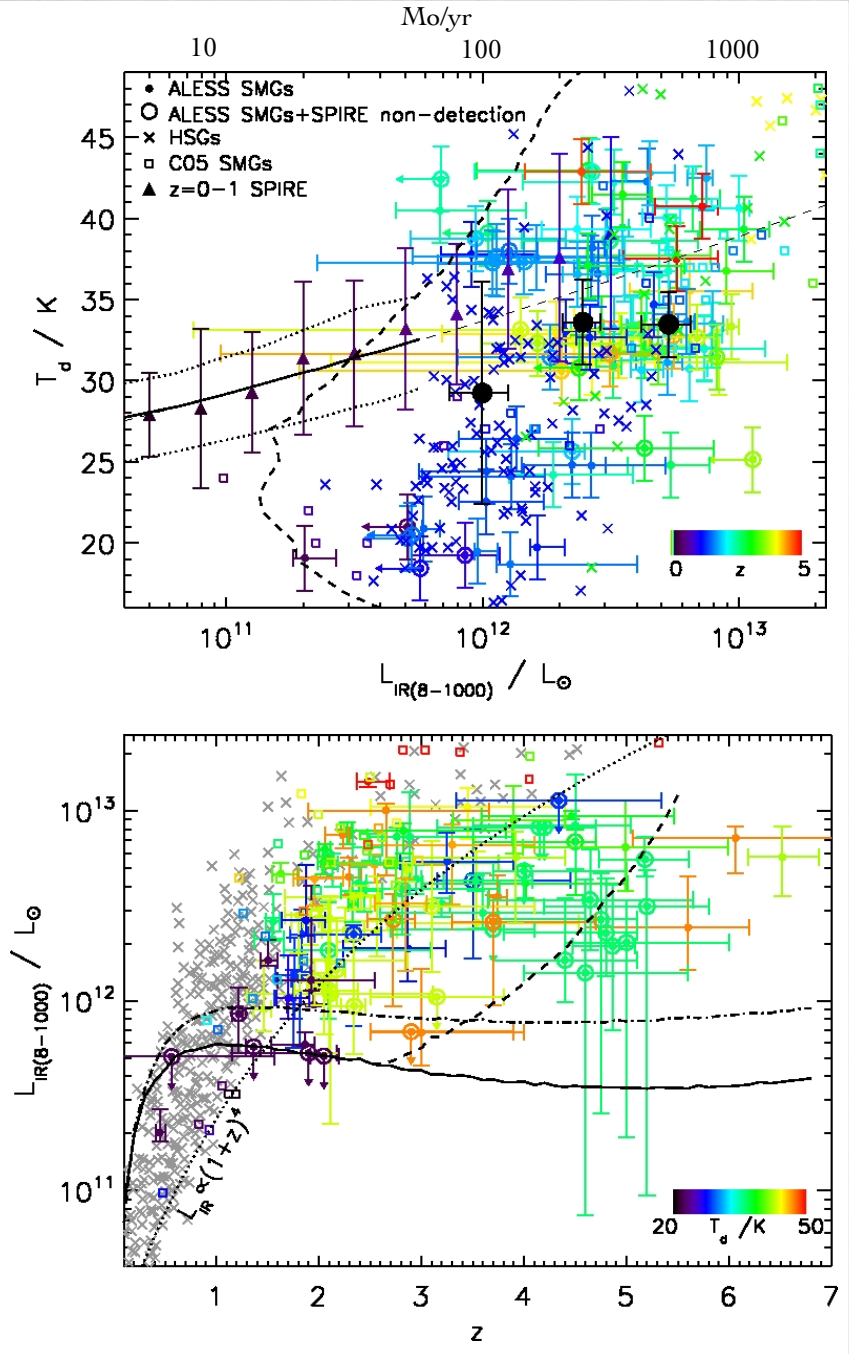
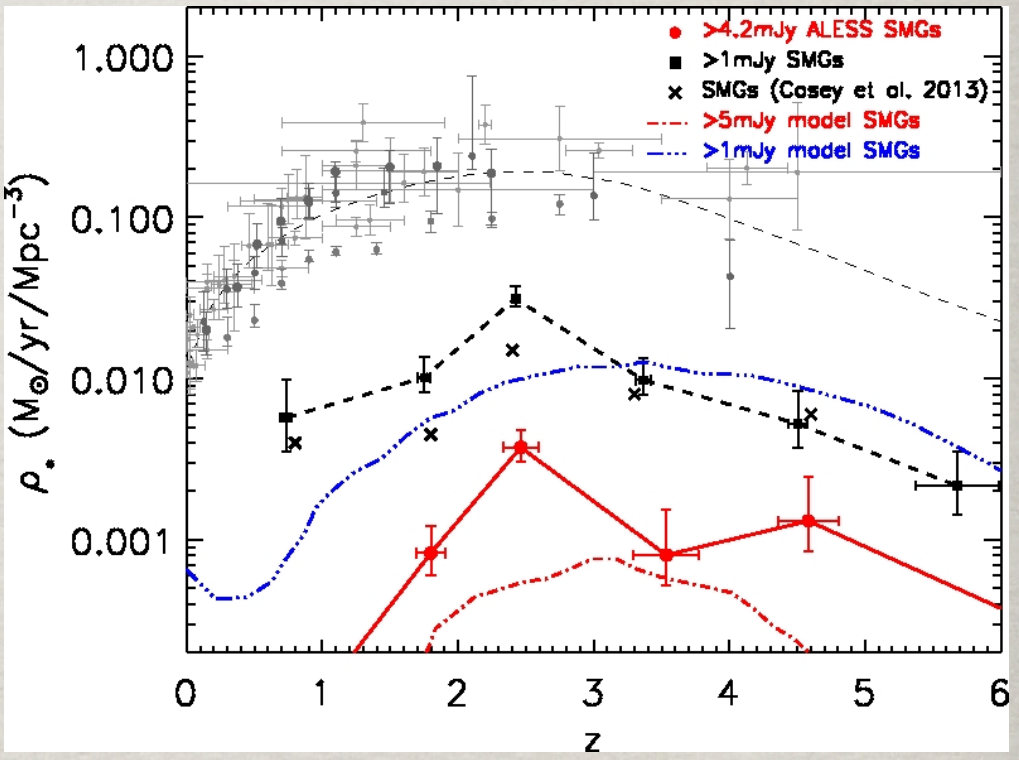
LESS124.4
LESS126.1
10^2
10^3
10^4
10^5


ALESS SMGs
z~1.5 ULIRGs
100.000
10.000
1.000
0.100
0.010
0.001
Flux (mJy)
1
10
100
1000
10000
wavelength (μm)
T = 120K
T = 60K
T = 30K
Composite rest-frame SED of 99 ALESS SMGs

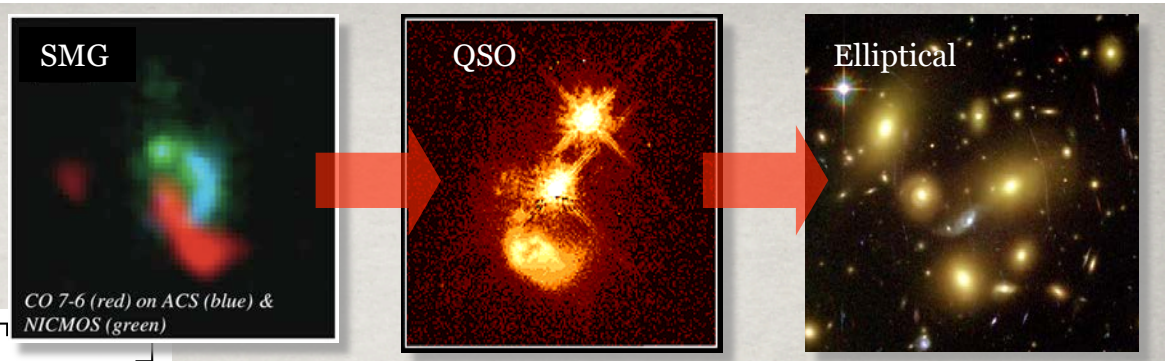
FIR luminosities, SFRs and total stellar masses

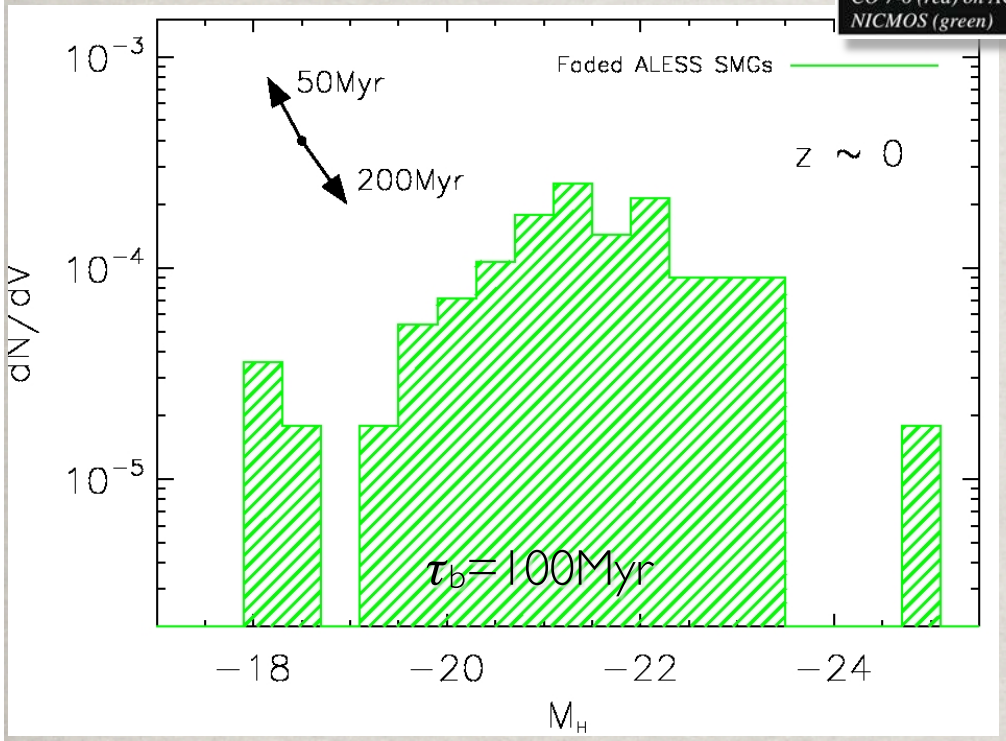


Integrating to S_{870} = 1mJy, SMGs host ~20% of cosmic SFR density at z=2.



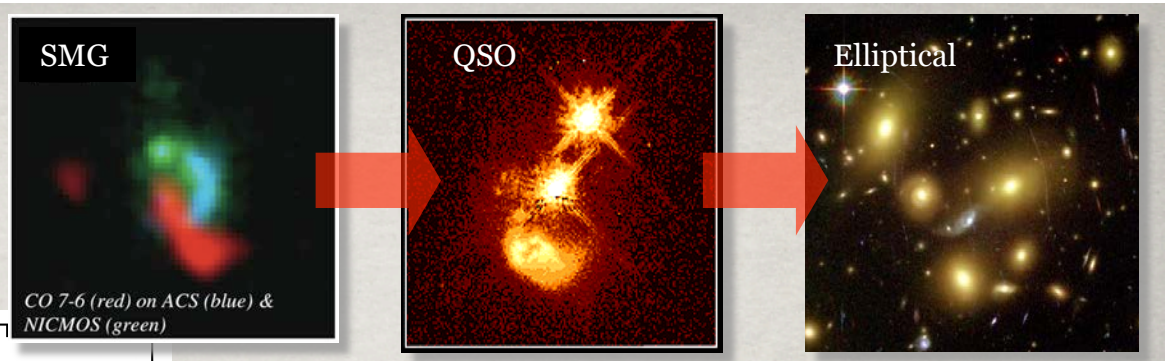
SMG Evolution to z=0

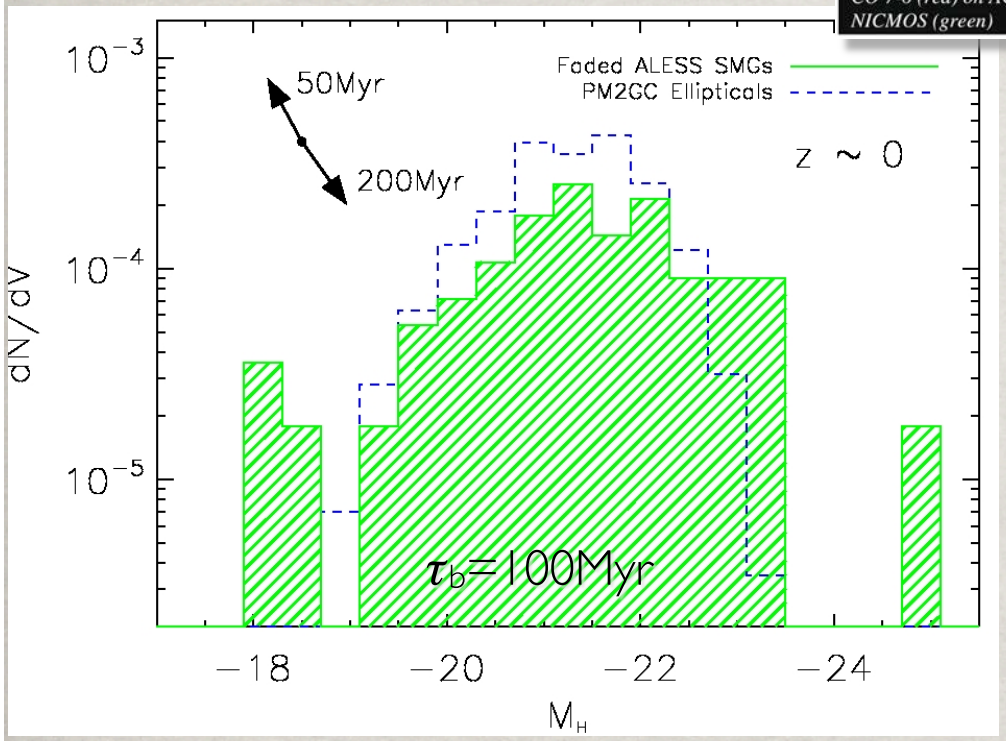




Take N(z); SFR; average lifetime and H-band fading (assume single burst) and calculate the space density of descendants at z=0

SMG Evolution to z=0

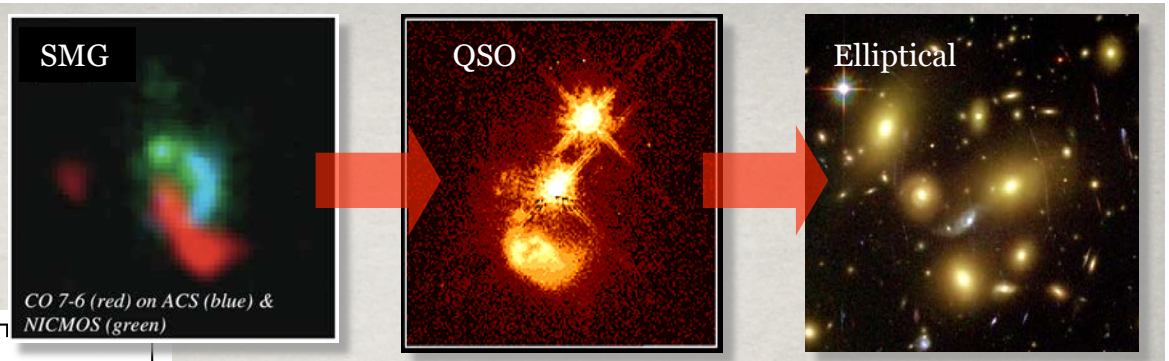


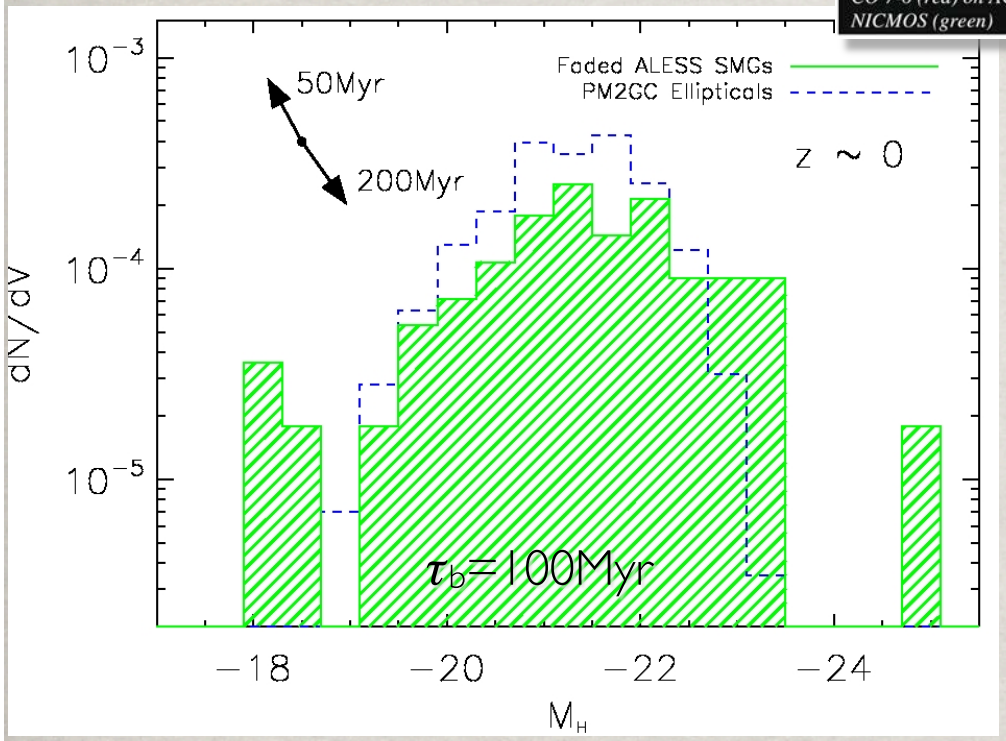


Take N(z); SFR; average lifetime and H-band fading (assume single burst) and calculate the space density of descendants at z=0

If the burst has a ~100Myr duration (compatible with the gas depletion timescales from M_{H2}/SFR ~ $4\times10^{10}M_o$/ $400M_o$/yr) and they only go through one burst then the space density and mass weighted ages of the faded SMG descendents are compatible with the majority of bright Elliptical galaxies at z=0.

SMG Evolution to z=0





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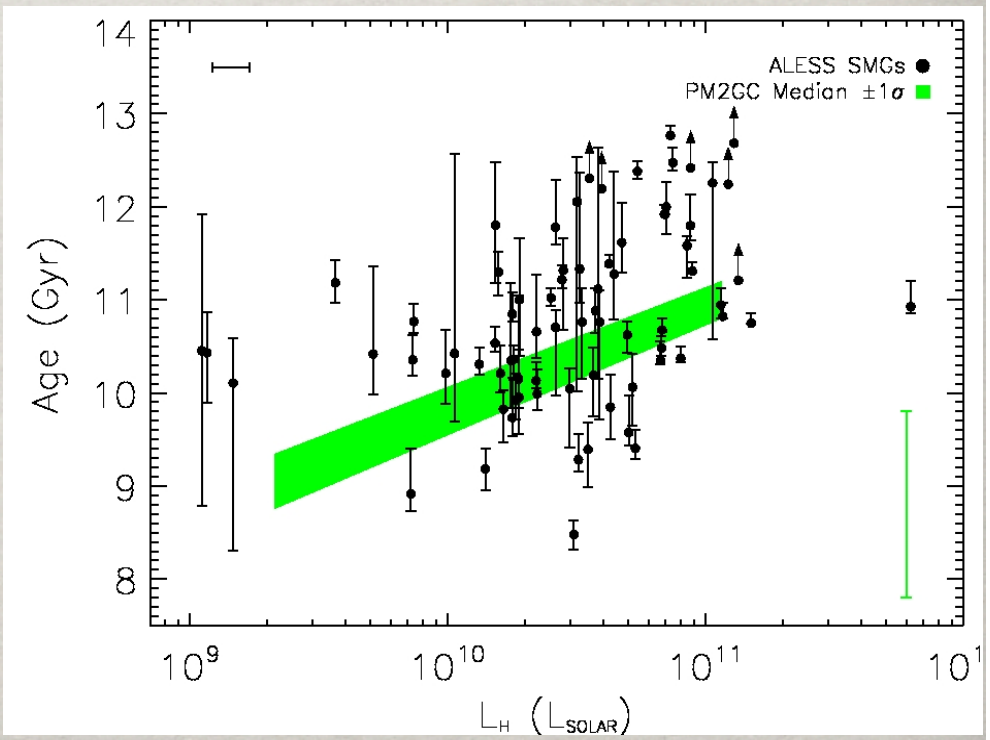

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Projects/Papers:

1. Catalogue paper + Multiplicity (Hodge et al. 2013 ApJ 768 91)
2. High resolution sub-mm counts. Influence of blending on counts (Karim et al. 2013 MNRAS 432 2).
3. Serendipitous z=4.4 [CII] identification & the evolution of the [CII] LF (Swinbank et al. 2012 MNRAS 427 1066)
4. OI 63-um detections in ALMA SMGs (Coppin et al. 2012 427 520)

5. N(z), stellar masses and evolution to z=0 (Simpson et al. 2013 ApJ submitted)
6. FIR colours, luminosities, SFRs (Swinbank et al. 2013 MNRAS submitted)
7. AGN fraction of ALESS SMGs (Wang et al. 2013 ApJ in press)
8. Sub-mm properties of star forming BzKs and BX/BMs from ALMA (Decarli et al. 2013 ApJ submitted)

9. FIR--radio correlation of ALESS SMGs (Thomson et al. 2013 in prep)
10. Energy balance in ALESS SMGs (E da Cuhna et al. 2013 in prep)

11. The rest-frame optical morphologies of ALESS SMGs from HST (Simpson et al. 2014 in prep)
12. zLESS: The redshift distribution and star formation histories of ALESS SMGs (Danielson et al. 2014 in prep)
13. A high resolution sub-mm continuum and HST morphological analysis of SMGs (Hodge cycle 1 program)

Conclusions

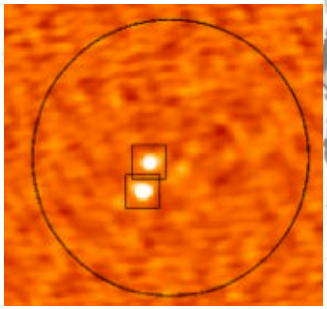
ALESS: 345GHz continuum mapping of 126 SMGs in ECDFS has produced unbiased sample of 99 robust SMG

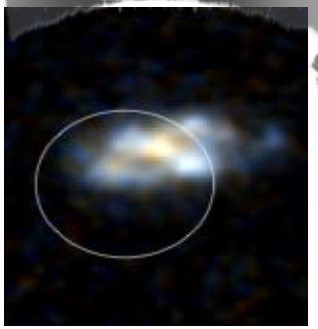
~1.4" resolution maps yield a high detection rate: ~50% single IDs; 30% multiple IDs; 20% blank maps. 1 SMG is resolved at 1.4" (12kpc) resolution. AGN fraction in ECDFS appears low - only 10% of ALMA SMGs detected in X-rays by Chandra.

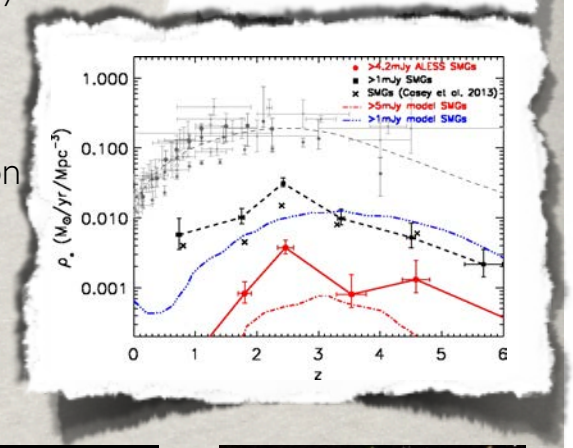
Redshift distribution suggests <z> =2.5+/-0.2, with a significant (but not dominant) tail to z~5.

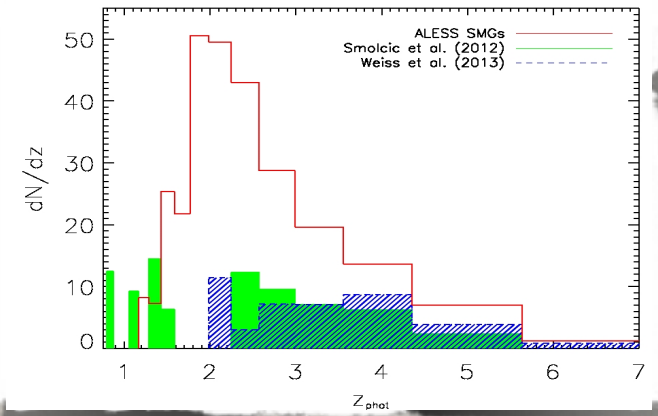
Fitting the rest-frame FIR SEDs, the bright SMGs account for ~2% of the cosmic SFR-density at z~2. Integrating to 1mJy, this rises to ~20%

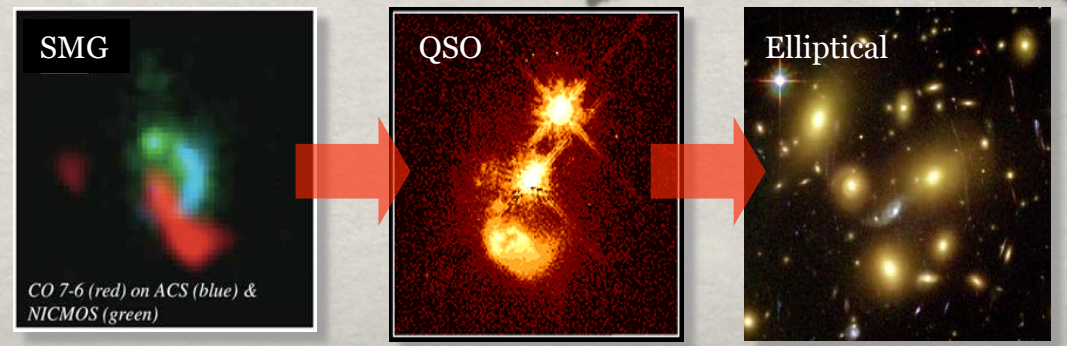
Accounting for the fading, the SMG descendent space density and magnitude distribution consistent with the population of morphologically classified luminous ellipticals.











ALESS: towards a full SMG catalogue

Hodge et al. 2013 ApJ 761 98

- 122/126 fields around LESS targets observed in Cycle 0
- 88 (strictly random) maps of homogeneous quality
- 99 SMGs at >3.5σ significance from the "best" maps (expect 1 spurious + 1 missed)
- 32 SMGs at >4σ significance from maps with poorer noise or outside PB (~30% incompleteness)

Robust counterparts: Reliability 80% but Completeness 45%; Robust + Tentative: Reliability 65% but Completeness 55%